Competitive effects of vertical integration in auctions

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Abstract

This paper studies the competitive effects of vertical integration between pharmaceutical drug producers and distributors in an auction setting. Utilizing data on 814,000 public procurement auctions in Russia, I identify the causal effect of vertical integration on the procurement prices of drugs. For drugs with few producers, vertical integration increases prices by 12%, while it decreases prices by 1.7% for drugs with many producers. I propose a model where distributors participating in a procurement auction negotiate with upstream producers. In the equilibrium, foreclosure explains the former empirical finding, while the exogenous synergy of the integration drives the latter effect. I use this model for the structural estimation of producer and distributor costs for drugs with two producers. Simulations show that a vertical merger with a synergy effect below 4% of the total cost harms the buyer. For a vertical merger with low synergy, the mandatory sharing of the production technology by the merging producer with a new independent firm is an effective remedy.

JEL classification: L42, D44, H57, I18

Keywords: procurement auction, pharmaceutical drug, vertical integration, competition, difference-in-differences, structural estimation, unobserved heterogeneity.

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1 Introduction

The vertical structure of supply chains is a key feature of many industries in which upstream producers distribute their goods via downstream intermediaries. Vertical integration is quite common in these industries as it helps to extend the business activity to the other levels of the vertical chain. The literature has made significant progress in understanding the effects of vertical integration for traditional retail markets, focusing on the trade-off between foreclosure and efficiency gains. In the last two decades, however, markets in which the intermediaries compete in auctions have received increasing attention. Markets such as online advertising, public procurement, and license selling represent a core economic activity of IT giants and national governments, with auctions and intermediation being key features. Currently, there is much debate regarding the evaluation of vertical mergers. The Federal Trade Commission in the US introduced new vertical integration guidelines in June 2020, and subsequently withdrew them in September 2021, arguing for the necessity *"to consider various features of modern firms, including in digital markets"*.[1] In the EU, there is an ongoing review process for vertical integration guidelines focusing on digital markets. However, there is neither theoretical nor empirical evidence regarding the effect of vertical integration when intermediaries compete in auctions.

The paper addresses this question by focusing on the Pharma industry. This industry has a vertical structure for the supply side: upstream producers manufacture drugs and disseminate them via downstream intermediaries (distributors and pharmacy networks). In many countries in which the public healthcare system is predominant, public hospitals and healthcare authorities constitute a significant demand for drugs to provide inpatient and outpatient treatments. These public buyers have to purchase drugs keeping necessary therapeutic treatment, on the one hand, and foster competition on the other. They achieve this dual goal in two steps. First, in a purchase announcement, the buyer sets a *drug specification*, defined as a combination of active ingredient and dosage, considering different brands as perfect substitutes. This brand substitution intensifies upstream competition among brand producers keeping the necessary level of therapeutic treatment. If there is a single producer of the active ingredient, the wholesale price cap regulated by the government limits the producer's monopoly power. Second, the buyer implements the purchase via a procurement auction, with a minimal price being the only criteria. This intensifies downstream competition among distributors.

[1] www.ftc.gov/news-events/press-releases/2021/09/federal-trade-commission-withdraws-vertical-merger-guidelines

This paper studies the effect of vertical integration between drug producers and distributors on prices in procurement auctions in a setting with brand substitution and price regulation. I collect data on more than 814,000 auctions for drug procurement in Russia from 2014 to 2019. The data include bidders' IDs and bids, as well as information about the drugs purchased, including active ingredients, dosages, prices-per-unit, number of drug units, and brands of the supplied drugs. I extend this with information on *vertical integration events* in the Russian Pharma industry, comprising five mergers and four divestitures. Several factors make the Russian drug procurement data an ideal source for studying the research question. First, the public procurement of drugs in Russia constitutes one-third of the overall pharmaceutical demand. Second, detailed bidding and contract information helps to identify vertical interactions between producers and distributors. Third, considerable heterogeneity in the number of producers and several vertical integration events, affecting 20% of the markets, provides substantial variation for the retrospective analysis of mergers.

I implement the analysis in three steps. First, I provide reduced-form evidence of the effect of vertical integration on the per-unit procurement prices of drugs. The detailed information about bidders and drug specifications enables the use of the difference-in-differences (DID) approach. The treatment group includes all drug specifications of producers from the integration events. In the DID analysis of mergers, the control group should be chosen with caution, as non-treatment group observations could be indirectly affected by the mergers (Choné and Linnemer (2012)). I overcome this issue by defining the control group as the set of drug specifications for the same broad class of diseases as drug specifications in the treatment group, but excluding the indirect substitutes. This choice for the control group helps, on the one hand, to achieve the parallel pre-trends and, on the other, not to include drug specifications that could be indirectly affected by the integration. The reduced-form analysis leads to an intuitive conclusion that the extent of upstream competition drives the price effect of vertical integration. If the upstream competition is soft, with at most four producers, vertical integration increases procurement prices by around 12%. A reduction in downstream competition is the primary driver of this effect for a single producer case. However, if the upstream competition is tough, with at least five producers, vertical integration decreases the prices by 1.7%. The results are stable to a set of robustness checks, including the stack regression approach from the modern staggered DID literature (Cengiz et al. (2019)).

Second, I propose a model to explain a mechanism for the vertical integration effect. In this

model, a public buyer announces a descending auction to purchase a drug, and the set of distributors are potential bidders. The negotiation stage precedes the bidding stage. Distributors negotiate with producers about the *input prices*, production costs are the private information of producers, and the regulated input price cap is common knowledge. When input prices are committed, distributors privately observe delivery costs and participate at the bidding stage. Under the vertical separation (VS) scenario, all producers and distributors are independent. Under the vertical integration (VI) scenario, the integrated distributor has an efficiency gain: double markup elimination and reduction in transaction costs (*synergy effect*). The model compares the ex-ante expected buyer payments under the VI and VS scenarios. For a single producer, in equilibrium, the producer sets the input price at the regulated cap for independent distributors in both scenarios. Therefore, the price setting for rival distributors cannot be a driver for the increase in the buyer payment under the VI scenario. However, I show that the integrated producer has incentives to restrict downstream competition, which leads to a higher buyer payment. For the case of only a few upstream producers, the VI effect is ambiguous as it depends on the cost distributions. The simulation for uniform cost distributions shows that the foreclosure effect dominates efficiency gains and harms the buyer. For the case of many producers, the foreclosure effect is negligible, and when the synergy effect is positive, the buyer payment is lower under the VI scenario.

The reduced-form approach is helpful as a retrospective analysis of mergers. However, it does not help in understanding ex-ante conditions to forbid vertical mergers and potential remedies (Nevo and Whinston (2010)). Moreover, the theory has ambiguous conclusions regarding the case of only a few producers owing to cost-distribution assumptions. Thus, at the third step of my analysis, I structurally estimate producer and distributor cost distributions and simulate vertical mergers under different conditions. I take the VS scenario of the model and choose a set of auctions, where the bidders are distributors, and two independent producers manufacture a drug specification. In the model, the input price of distributors represents an unobserved heterogeneity because the researcher does not observe the outcomes of the negotiation stage. Following the literature on the structural estimation of English auctions with unobserved heterogeneity (Freyberger and Larsen (2017)), I identify the distributions of input prices and distributor costs. The structure imposed on the negotiation stage enables further deduction of producers' cost distribution based on the input price distribution. Next, I use the cost distributions to simulate vertical mergers under different conditions. As a first result, I show that a vertical merger without a synergy effect

doubles the profit of the integrated firm compared to the aggregate profit for a separated producer and distributor. However, the merger increases the buyer payment by 17%, so it should not be approved. As a second result, I show that a vertical merger with a synergy effect below 4% of the total cost harms the buyer. I match the effect of vertical mergers from structural model simulations with the reduced-form effect and estimate the synergy effect at around 0.5%–1.5% of the total cost. Moreover, the transaction costs of participants in Russia are around 1% of the procurement value (Balaeva et al. (2020)), representing the primary source for integration synergy. Therefore, a 4% synergy effect for integration is a challenging goal. Finally, I propose a remedy for mergers when synergy is low. I show that the exogenous entry of a third independent producer after the vertical merger, with a 1% synergy effect, reduces buyer payments by 6% and that the merger is profitable for the integrating firms. This suggests that the mandatory sharing of the production technology by the merging producer with a new independent firm is an effective remedy.

Despite using empirical evidence from Russian public procurement only, the results have external validity for other countries with public healthcare systems. Two key features of procurement regulation drive the theoretical and empirical results: price regulation for a single producer; and brand substitution for several producers. The same drug procurement features exist in many EU countries and large developing countries such as China, India, and Brazil, making the paper's findings externally valuable. Moreover, in the US, brand substitution is also a common practice in drug prescriptions for consumers (Bronnenberg et al. (2015), Song and Barthold (2018)), so the results can be a starting point for studying the vertical interactions between drug producers and distributors.

Literature and contribution

The theoretical literature on vertical integration is abundant, mainly discussing conditions in which foreclosure or the efficiency gain effect dominate (Salinger (2014), Fumagalli et al. (2018)). However, the empirical evidence is scarce (Slade (2020)). The literature finds that both foreclosure and efficiency gain effects occur, with the overall effect depending on markets and their structure. Hortaçsu and Syverson (2007), Gayle (2013), Atalay et al. (2014), Gil (2015), Asker (2016), Atalay et al. (2019) found no foreclosure. Crawford et al. (2018) showed the prevalence of efficiency gains on average, but that foreclosure is still a major concern. On the contrary, Hastings and Gilbert (2005), Normann (2011), and Lee (2013) demonstrated the harmful effect of vertical integration. Luco and Marshall (2020) showed that efficiency gains induce the anticompetitive effects

of integration in a multiproduct industry.

The paper contributes to the vertical integration literature in two ways. First, I theoretically and empirically study the VI effect on buyer prices when downstream firms compete in auctions. All empirical literature on vertical integration has studied the downstream competition in ordinary markets. The difference can be substantial (Klemperer (2007)). In the auction setting, competing products are perfect substitutes and only price matters. In ordinary markets, product differentiation in terms of geographical location or characteristics is also a relevant dimension of vertical integration evaluation (Houde (2012), Allain et al. (2017)). Therefore, if the efficiency gain effect dominates and is passed through, the buyer can fully internalize it in the auction setting, but not in ordinary markets. Several papers studying vertical integration in auctions (Thomas (2011), Loertscher and Riordan (2019), Waehrer (2019)) have considered integration between a bidder and the auctioneer. This, however, is substantially different from the public procurement setting I study here or similar settings in online advertising and license selling, encompassing mergers between bidders and upstream input suppliers (Klemperer (2002), Athey et al. (2011), Decarolis et al. (2020), Decarolis and Rovigatti (2021)). Second, most studies on vertical integration have considered highly concentrated markets because foreclosure is thought to be a threat (Lafontaine and Slade (2007), Riordan (2008), Salinger (2014), Nocke and Rey (2018)). The exceptions to this are Riordan (1998) and Loertscher and Reisinger (2014). The latter paper considers a model for downstream firms buying an input capacity from the upstream market. It shows that an increase in competition at the *downstream* level increases the anticompetitive effects of vertical integration. The present paper, however, studies the VI effect depending on the *upstream* competition, and the findings align with standard anti-trust reasoning.

This paper also contributes to the literature on the structural estimation of auctions. Unobserved heterogeneity, encompassing factors observable by bidders but not by the econometrician, is common in the literature (Krasnokutskaya (2011), Athey et al. (2011), Hu et al. (2013), Decarolis (2018), Larsen (2021)). These factors are an essential component of bidders' costs in the procurement of non-standardized goods. Although drugs are standardized products, my model rationalizes the unobserved heterogeneity as an equilibrium input price at the negotiation stage. This enables the costs of intermediaries and input suppliers to be identified separately, which is novel in the literature.

The paper also contributes to Pharma industry studies. This is the first paper to study vertical

mergers; in contrast, Björnerstedt and Verboven (2016), Newham et al. (2018), Bonaime and Wang (2019) studied horizontal consolidations in Pharma.[2] Regarding the drug-procurement literature, this is one of few papers focusing on the structure of the supply side (Dubois et al. (2021)); most others have focused on the organization of the demand side (Duggan and Scott Morton (2010), Jascisens (2017), Brugués (2020), Cao et al. (2021), Wu (2021)). This paper also extends our understanding of producer and distributor profits in the Pharma industry (Dubois and Lasio (2018), Dubois and Sæthre (2020)).

2 Institutional setting

In Russia, public organizations such as hospitals and polyclinics provide most healthcare services free of charge. These services include both inpatient and outpatient treatment. Moreover, several national and sub-national (regional) healthcare programs help to protect the population. Some of these programs are seasonal (e.g. vaccination against influenza) or may depend on the epidemiological situation (e.g. to mitigate the spread of tuberculosis). Other programs are permanent and are focused on protecting specific groups of the population, e.g. kids vaccination, provision with drugs and medical devices of people who have pancreatic diabetes, treatment of cancer diseases, and orphan (rare) diseases. Healthcare authorities and public hospitals permanently purchase pharmaceutical drugs via procurement auctions to implement these healthcare services.

Public Procurement (PP) of drugs accounts for 560 billion RUB in 2019 (approximately 8.5 billion USD) and constitutes 35% of the overall pharmaceutical demand in Russia. Public procurement is regulated by 44 Federal Law (FL) for budget-funded organizations and by 223 FL for semi-autonomous organizations and state-owned enterprises. 44 FL is a rigid regulation requiring public buyers to follow specific procurement procedures depending on timing and value. On the other hand, 223 FL is a flexible regulation. It only imposes a scope of competitive procurement regulation, while organizations define specific thresholds and procedures in their internal rules. While few large and competent hospitals can choose to follow 223 FL, the dominant part of public hospitals and healthcare authorities have to follow 44 FL. This paper studies procurement auctions according to 44 FL only since public buyers must follow the same procurement procedures.

[2]There is also a strand of literature studying horizontal consolidations in industries with a vertical structure Bushnell et al. (2008), Hosken et al. (2011) Dafny et al. (2012), Gowrisankaran et al. (2015), Schmitt (2017), Craig et al. (2019), Dafny et al. (2019), Iossa et al. (2019), Carril and Duggan (2020), Decarolis and Rovigatti (2021).

Moreover, purchases according to 223 FL constitute only 8% of public procurement for drugs.

44FL prescribes to use one of three procedures to procure a drug: (i) *direct purchase* without competitive procedure, with upper bound for the contract value of 200 K RUB (3.1 K USD); (ii) *request for quotations* in the form of first price seal-bid auction, with upper bound for the reserve price of 500 K RUB (7.9 K USD); (iii) *electronic open descending auction* (e-auction) without any restriction on the reserve price.[3] Hereafter, I consider e-auctions only as they constitute the dominant part of purchases in numbers and money value.[4]

Many drugs of different brands have similar therapeutic treatment, as they use the same active ingredient.[5] Taking this into account, a public buyer announces a *bundle* of drugs for purchase. Namely, for each drug in the bundle, the procurer indicates:

1. *Drug specification* containing:

    - active ingredient (AI) of the drug (e.g. Insulin glargine), but not a brand (e.g. Lantus SoloStar of Sanofi);
    - AI dosage (e.g. 100 un/ml, 3 ml);
    - drug form (e.g. solution for infusions).

    All brands with the same AI, dosage, and drug form are considered perfect substitutes.

2. *Quantity:* Number of units in pack and number of packs (e.g. 5 units/pack, 2 packs).

3. Reserve price-per-pack (e.g 3765 RUB/pack (around 60 USD)). If the active ingredient is from the list of *essential drugs*, prices of brands containing this AI are regulated at two levels – national and regional – imposing upper bounds at each of them. Wholesale prices from producer to distributors are regulated at the national level, and retail prices, including distributor and pharmacy network markups, are regulated at the regional level. Regulated prices of different brands with the same AI can differ. The reserve price-per-pack in the

[3]There are another two procedures, though rarely used for drug purchases: (i) request for proposals – if a hospital purchases a specific drug for a particular patient and committee of doctors should substantiate the necessity of this purchase; (ii) scoring rule auction, where a public buyer can use qualification criteria. In total, these procedures constitute less than 1% of my sample, so I exclude them from the analysis as their procurement procedure is different.

[4]In my sample there are 8.2% of direct purchases and 4% of request for quotations.

[5]Anatomical Therapeutic Chemical Classification (ATC) classifies all active ingredients according to a hierarchical structure in five levels. Figure A1 shows this classification for insulin glargine, which has ATC code at the fifth level A10AE04. Later, I will use this classification to create treatment and control groups for reduced-form estimation.

auction should contain the producer regulated price and distributor markup.[6]

Aggregating in standard way over drug specifications in the bundle, the buyer calculates the reserve price for the bundle, which becomes the public reserve price of the auction. The buyer also specifies delivery duration and location.

If a distributor plans to apply for participation, he negotiates with producers and finally agrees with one of them to get a certificate. The certificate indicates the producer willingness to provide the necessary brand via the distributor.[7] Participants in the auctions are mostly intermediaries – distributors and pharmacy networks.[8] Bidders compete solely in price by placing their *bids for the bundle* according to standard rules of open descending procurement auction with a public reserve price for the bundle. A firm with minimal offer wins. It signs the procurement contract, implements trade with the producer and supplies the bundle according to the announced terms.

Two features of the regulation are essential: (i) price regulation for *essential drugs* and (ii) brand substitution. These features are not a peculiarity of Russian public procurement, but it is common for many countries of the European Economic Area with public healthcare systems and China, India, Brazil, and many others.

3 Data

To study the effect of vertical integration, I use three datasets. The first dataset is a population of public procurement contracts from July 2014 to September 2019, purchasing anti-neoplastic drugs, systemic antimicrobial drugs, drugs for treating pancreatic diabetes and diseases of the circulatory system. I collected this dataset from the FTP server of the official public procurement website (www.zakupki.gov.ru), and enriched it with the commercial data on drugs classification from IAS Zakupki (www.krasoft.site).[9] This dataset covers 75% of total spending on all types

[6]The choice of brand to incorporate the producer regulated price into the reserve price is at the discretion of the buyer.

[7]Different distributors can receive certificates from the same producer. A producer certificate is a compulsory document for large auctions with one drug specification in the bundle. Certificates of all applicants are screened before the auction, so applicants without certificates are forbidden to bid.

[8]Producers prefer not to bid directly in the auctions because of substantial distribution and transaction costs.

[9]Standardization of drug specification description and measuring price-per-unit and quantity of units is a complicated task. Public buyers may use different measures of dosage (e.g. for infusions they use dosage description interchangeably as "100mg/ml" or "10%") and different measures of unit (e.g. some buyers calculate the number of packs and other calculate the total number of units, i.e. number of drug units in pack times number of packs). Typos in brands and AI of drugs are also a fundamental problem. Several private firms collect data from the official website and use supervised machine learning classification techniques and extensive human resources to make the

of drugs procured according to 44FL. The original dataset has 946 thousand bundles containing information about 2.8 million drugs. Each bundle corresponds to a contract. Auction participants place bids for a bundle, but the winning bidder's contract specifies the price-per-unit for each drug of the bundle. Hereafter, *drug specification* means a unique combination of an active ingredient and dosage[10]. Drug specification is the natural level of clustering all the drugs in my sample, as competition in auctions occurs at this level. Therefore, each drug specification is a separate market. [11]At the drug level, the data contains the drug description (drug specification and brand), the quantity of units and contract price-per-unit specified by the supplier. At the bundle level, the data includes bundle reserve price, procurement procedure, number of applicants, ID (fiscal code) and final bid of each bidder, ID of the winner, contract signing date and contract duration. For the analysis, I keep only purchases via electronic open descending auction (e-auctions). They constitute 87% of observations at the bundle level and 93% at the drug level. I also exclude drugs whose drug specification occurs less than ten times in my sample or whose price-per-unit is unreliable[12]. Final sample includes 814,684 contract bundles corresponding to 2,515,412 drugs. 83% of these drugs are from the list of essential drugs, i.e. their prices are regulated.

The second dataset is an official roster of all drugs in Russia registered and certified for sale (grls.rosminzdrav.ru). This dataset includes the brand and name of the corresponding producer. By matching the brands of the first and second datasets, I create a list of drug specifications manufactured by each producer in the procurement sample.

The third dataset is a list of all partial mergers, full mergers and divestitures in the Pharma industry in Russia. The core dataset comes from Zephyr of Bureau van Dijk. I manually extend this list by corporate events from Russian pharma and business media[13]. Among all vertical

description of drug specifications standardized. IAS Zakupki (krasoft.site), Headway Company (hwcompany.ru), IQVIA (iqvia.com), Cursor (cursor-is.ru) among them demonstrate the high quality of classification. Large domestic and international pharmaceutical companies working in Russia as Johnson and Johnson, GlaxoSmithKline, Alcon, R-pharm and pharma media use data of these firms to analyze public procurement of drugs.

[10]This definition omits "drug form" compared to what public buyers specify in an auction announcement. However, it is not restrictive since my final sample has 2013 unique active ingredient-dosage combinations and 2134 ingredient-dosage-drug form combinations. At the same time, some descriptions of drug forms vary over different buyers even if it is the same drug.

[11]In the main analysis, I do not take into account the geographical split of the markets because of two reasons: (i) regulation of prices of drug producers takes place at the national level irrespectively of their production location, (ii) the group of drugs I analyze is essential for social programs of the government, so the supply of these drugs to all the geographical regions is highly stimulated by government. Since supply to different regions is associated with varying distribution costs, which is the responsibility of distributors, I will control for buyers' locations via regional fixed effects.

[12]Within each drug specification, I exclude observations whose price-per-unit is either below 1% percentile or above 99% percentile.

[13]Among them forbes.ru/tegi/lekarstva, gmpnews.ru, vademec.ru, dsm.ru/marketing/free-information/analytic-

mergers and divestitures (hereafter *VI events*) between producers and distributors during 2014-2019 (15 VI events), I choose VI events that have enough pre- and post- VI event observations in my procurement data, so nine VI events are remaining.[14] Table A1 of the Appendix shows these VI events. There are three full mergers, two partial mergers, and four divestitures. Hereafter, I call producers involved in these VI events as *VI producers*, and distributors involved in these VI events as *VI distributors* irrespectively of the period before or after the VI events. Other producers are called *Non-VI producers* and *Non-VI distributors*, respectively.[15]

Table 1 shows the descriptive statistics at the drug level with the breakdown by winning distributor and producer of drug specifications. The table shows that both VI distributors and Non-VI distributors supply drugs of both types of producers. The number of drug specifications produced by VI producers is 4.5 times lower compared to Non-VI producers.[16] The normalized price of drug specifications produced by VI producers is lower compared to the prices of Non-VI producers. VI distributors have lower prices of drugs compared to Non-VI distributors.

Table 1: Descriptive statistics at the drug level

Win. distributor	Producer	Obs.	Drug spec.	Mean z-price	Median z-price	St.d. z-price
Non-VI distrib.	Non-VI prod.	968598	1614	0.002	-0.063	0.999
Non-VI distrib.	VI prod.	1490452	399	0.000	-0.212	1.001
VI distrib.	Non-VI prod.	38178	1218	-0.016	-0.166	0.987
VI distrib.	VI prod.	18184	227	-0.077	-0.276	0.963

Note. The table shows descriptive statistics at the drug level for the final sample. Column *Win. distributor* shows if the VI distributors supplied the drug. Column *Producer* shows if the drug specification of the supplied drug is produced by the VI producers. Column *Obs.* means the number of observations in this category. Column *Drug spec.* counts the number of different drug specifications in this category. The last three columns are mean, median, and standard deviation of the within drugs specification normalized price. To get z-price, from the price-per-unit of each observation, I subtract the average and divide by the standard deviation of prices of other observations within drug specification.

Table 2 shows descriptive statistics at the bundle level for the final sample. The average bundle reserve price is 2.7 M RUB, but 25% percentile is 200 K RUB, and 75% percentile is 1.56 M RUB. The average bundle contains 2.7 different drug specifications, and the average drug

reports, home.kpmg/ru/ru/home/insights

[14]For each VI event I calculate the number of drugs, with drug specifications manufactured by the producer involved in this VI event and supplied by the distributor involved in this VI event. I keep only those VI events that have at least ten observations at the drug level in 2 quarters pre- and post- VI event.

[15]Notice, non-VI distributors are not necessary distributors that do not own (or are not owned by) any producer. My definition means that Non-VI distributors do not change their vertical ownership structure during July 2014 - September 2019. The same holds for non-VI producers.

[16](626=399+227) vs. (2832=1614+1218).

Table 2: Descriptive statistics at the bundle level

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Bundle reserve price (M RUB)	814,684	2.73	26.55	0.001	0.20	1.56	8,332.50
Number of distinct drug spec.	814,684	2.69	4.84	1	1	2	135
Drug spec. HHI	814,684	0.67	0.38	0	0.3	1	1
Bundle has drug spec. of VI prod.	814,684	0.53	0.50	0	0	1	1
Share of drug spec. of VI prod.(%)	814,684	38.88	45.06	0	0	100	100
Number of applicants	813,523	2.73	2.16	1.00	1.00	4.00	23.00
Rebate for bundle (%)	803,983	11.63	18.25	0.00	0.00	18.31	80.00
VI distrib. applies	814,684	0.073	0.260	0	0	0	1
VI distrib. wins	814,684	0.025	0.155	0	0	0	1

Note. The table shows descriptive statistics at the bundle level for the final sample. *Drug. spec. HHI* is the HHI index calculated via the value shares of each drug specification in the bundle. *Share of drug spec. of VI prod.* is the value share of drugs in the bundle, whose drug specifications are manufactured by VI producers.

HHI concentration in the bundle is 0.67. 53% of bundles contain at least 1% of drugs with drug specifications of VI producers. The average share of these drugs is 38.9%[17], though 75% percentile is 100%. It means that at least 25% of e-auctions purchase bundles containing only drug specifications produced by VI producers. The average number of applicants is 2.73, where 25% percentile is one, and 75% percentile is four. The average auction rebate for a bundle is 11.6% of the reserve price. VI distributors participate in 7.3% of these auctions and win in 2.5% of all 814,684 auctions, i.e. they win in 34% of auctions they participate.

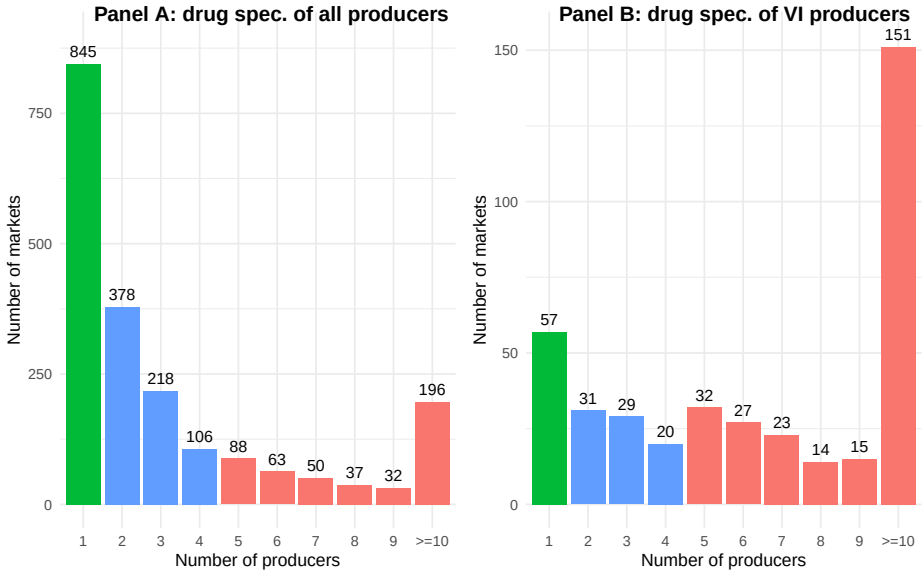
Another essential aspect to understand is how competitive markets are. Figure 1 shows the distribution of the number of producers by drug specifications.[18] Panel A shows that 845 markets are monopolized, and 702 markets have from two to four producers. Panel B shows that VI producers participate in some of these highly concentrated markets. VI producers monopolize 57 markets, and 80 markets have from two to four producers.

The descriptive statistics show that bundles often include several drug specifications, some of which are often produced by VI producers. Moreover, VI producers are among few others for some drug specifications. VI distributors actively participate in the auctions by supplying both drugs produced by VI producers and other drugs.

[17]Share of a drug in the bundle is calculated as the ratio of monetary value of the drug to the contract value in percentage.

[18]The number of producers for each drug specification is defined as the number of distinct producers manufacturing brands with this drug specification ever supplied to public buyers in my data.

Figure 1: Distribution of the number of producers by markets



Note. The market is defined as drug specification. Panel A shows the distribution of the number of producers by markets for all drugs in the sample. Panel B shows the same distribution for drug specifications produced by VI producers, i.e. markets, where VI producers act. Drug specifications with more than ten producers are binned at the bin of ten producers.

4 Reduced-form evidence

4.1 Identification

I use the difference-in-differences design at the drug level to estimate the effect of VI on the price-per-unit of drugs. Recall that each drug specification – a unique combination of the active ingredient and dosage – is a separate market. For each VI event, I construct a list of drug specifications whose brands are manufactured by VI producer associated with this VI event. Combining these lists over VI events I say that a procured drug is in the *treatment group* if its drug specification is from this combined list. This definition means that treatment is defined at the market level, and each VI event can affect different markets.[19] This definition of treatment group helps to estimate the VI effect both for auctions, where VI distributors participate, and where they do not. The Control group should be such that: (i) parallel trend assumption in pre- VI event

[19]While this definition is conceptually correct, the complexity arises because of the staggered nature of the VI events. The same markets can be affected several times by different VI events. To take this into account, I refine this definition as follows. For each VI event, I say that a procured drug is in the treatment group if its drug specification is manufactured by VI producer (as a specific brand) and supplied by either VI distributor associated with this VI event or by Non-VI distributors. That is, for the VI event under consideration, I do not ascribe a drug with drug specification produced by VI producer of this event to the treatment group if it is supplied by VI distributors associated with other VI events. Since VI distributors win only 2.5% of all the auctions (see Table 2), such refinement is not substantially different from the basic definition.

period holds, (ii) control group does not react to the VI events. Therefore, the dynamics of the control group should resemble the dynamics of the treatment group before the VI events, but the control group should not include indirect substitutes for the drugs in the treatment group. This is well recognized problem in the DID estimation of mergers (see e.g. Choné and Linnemer (2012)). Recall that all active ingredients are classified by hierarchical Anatomical Therapeutic Chemical Classification (ATC) with five levels. As an example, Figure A1 shows this classification for insulin glargine, which has ATC code at the fifth level A10AE04. I define a drug as a substitute if its active ingredient belongs to the same Level 4 ATC subclass as a drug in the treatment group. Next, I construct a list of Level 3 ATC subclasses containing all active ingredients of drugs in the treatment group. Drugs that are not in the treatment group and are not substitutes but whose active ingredients belong to this list of Level 3 ATC subclasses are assigned to the control group. For example, suppose drug specifications with insulin glargine are in the treatment group. In that case, all other drugs, which are not in the treatment group and whose ATC4 level subclass is A10AE are substitutes (i.e. drugs with ATC5 level subclasses A10AE01 - A10AE03, A10AE05-A10AE07), and drugs with ATC4 level subclasses A10AB, A10AC, A10AD, A10AF are in the control group (see Figure A1). Table A2 of the Appendix shows the descriptive statistics for the treatment and control groups with breakdown by type of suppliers.

I implement the difference-in-differences approach with multiple VI events and different intensities of the treatment. Assume there exists a model for price-per-unit of a drug of the following form:

$$\begin{aligned} ln(price_{q,d,i,t,b,s}) =& \alpha I(d \in D, t \in T) \cdot Intensity + [\beta Num.Applicants_i] + \\ & \delta_q + \mu_d + \lambda_t + \eta_b + \gamma_s + \nu_{ATC3-year} + \mathbf{X_i}\theta + \varepsilon_{q,d,i,t,b,s}, \end{aligned} \tag{1}$$

where q units of the drug with drug specification d are procured in auction i at quarter-year t by a buyer from region b and supplied by firm s. D is a treatment group. T is a post- VI event period. $Intensity$ equals 1 for full mergers, 0.5 for partial mergers, -1 for divestitures. Set of indicator variables δ_q specifies within drug specification quantity percentiles.[20] Other variables are fixed effect for drug specification μ_d, year-quarter of contract signing λ_t, buyer region η_b, and

[20] One cannot use the quantity per se as different drug specifications are measured in different units, e.g. tablets, flacons. Moreover, even tablets of different drug specifications are not comparable. I use five equally spaced percentiles with cutoffs 20%, 40%, 60%, 80%, and within clusters, defined at the level of drug specifications, I assign each quantity to one of five 20%-percentiles.

supplier ID γ_s. Vector X_i is a set of auction characteristics: the number of drug specifications in the bundle, contract duration, indicator if a centralized authority implements procurement. Vertical mergers and divestitures are not random events. Firms have some expectations about the evolution of the markets and make the integration decision. To mitigate this problem, I control for dynamic expectations about markets via ATC3-year fixed affects $\nu_{ATC3-year}$. Noteworthy, if a merger involves many markets, then for each particular market this merger can be thought of as exogenous shock (Dafny et al. (2012), Ashenfelter et al. (2015), Chandra and Weinberg (2018), Decarolis and Rovigatti (2021), Rossi (2019), Carril and Duggan (2020)). Table A2 shows that producers associated with VI events work in at least 16 markets, with most of them working in at least 67 markets. Moreover, if firms have expectations about the merger other than for price-cost margin in public procurement – for example, improvement of quality and better differentiation in retail markets – this would be orthogonal to treatment in public procurement, as procurement regulation disregards the quality dimension via the brand substitution.

In specification (1) without control for the *Number of Applicants*, the coefficient α shows the aggregate effect of VI on the logarithm of price. It includes the direct impact on the price (e.g. raising rivals' costs and efficiency gain) and an indirect effect via the change in the downstream competition (e.g. exclusion of rival distributors). However, if one controls for the *Number of Applicants* in (1), then coefficient α shows just the direct effect fixing the downstream competition. Therefore, the change in coefficients α of the models with and without *Number of Applicants* as a control helps to separate direct and indirect effects of vertical integration.

In addition to the average effect of vertical integration, it is necessary to study the heterogeneity of the effect, i.e. how the VI affects prices depending on the number of drug specification producers. Therefore, I extend the model (1) in the following way:

$$\begin{aligned} ln(price_{q,d,i,t,b,s}) =& \alpha_1 I(d \in D, t \in T) \cdot Intensity \cdot I(\#drug.spec.producers = 1) + \\ & \alpha_2 I(d \in D, t \in T) \cdot Intensity \cdot I(\#drug.spec.producers \in \{2,3,4\}) + \\ & \alpha_3 I(d \in D, t \in T) \cdot Intensity \cdot I(\#drug.spec.producers \geq 5) + \\ & + [\beta \ Num.Applicants_i] + \delta_q + \mu_d + \lambda_t + \eta_b + \gamma_s + \nu_{ATC3-year} + \mathbf{X_i}\theta + \varepsilon_{q,d,i,t,b,s}, \end{aligned} \tag{2}$$

where coefficients α_1, α_2 and α_3 show the VI effect for the single producer, several producers (from two to four) and many producers (above five) cases. I use two sub-samples: (i) auctions,

where VI distributors participate; (ii) auctions, where only Non-VI distributors participate. For the first sub-sample, foreclosure and efficiency gains are in place. The second sub-sample serves as a placebo test for the VI effect, as the VI producer behaves as an independent upstream firm.

Endogeneity of Number of applicants.

Note that the *Number of applicants* in equations (1), (2) is an endogenous variable by several reasons. First, it is endogenous because the VI producer may have incentives to foreclose downstream distributors. Second, if application is costly, then a potential bidder decides to apply only if the expected profit is higher than the participation cost (Samuelson (1985), Levin and Smith (1994)).[21] Finally, when the collusion between bidders is an issue, the *Number of applicants* is a nominal measure of competition, while the true measure of competition would be the number of independent groups of bidders. As the primary goal to control for the *Number of applicants* is to isolate the indirect VI effect related to foreclosure, I propose a set of instruments related to the first reason. As a robustness check, I consider an alternative instrument related to the other two reasons and combine these two sets of instruments.

To construct instruments, I use an approach that becomes standard for estimating the effect of competition on prices in ordinary markets. This approach proposes to instrument competition by a merger induced change in expected competition (Dafny et al. (2012), Ashenfelter et al. (2015), Chandra and Weinberg (2018), Decarolis and Rovigatti (2021), Rossi (2019)). The main assumption is that the merger affects many markets, which is plausible in my setting.[22] Recall a buyer announces a bundle, and the VI producer may not manufacture all bundle components. It implies that the *Share of treated drugs* in the bundle – value share of drug specifications of VI producer in the bundle – can be a measure of auction bundle exposure to the treatment. I use this share (denoted $Share_i$) and its interaction with post-VI period ($Share_i \cdot I(t \in T)$) as instruments for the number of applicants. These variables are relevant instruments. Indeed, if the share of treated drugs is high, the VI producer may have incentives to foreclose the rival distributors. Moreover, in this case, the VI distributor has a substantial cost advantage, which disincentivizes the rival distributors from participating due to lower expected profit. These instruments are valid, i.e. they satisfy exclusion restrictions in the price equations (1) and (2). Indeed, the public buyer orders a bundle of drugs, so all bidders take it as given. Second, I directly control for bundling via

[21] Different variants of this endogenous entry are discussed by Gentry et al. (2018).

[22] See Table A2 and discussion above.

the number of drug specifications in the structural equations (1) and (2), so additional variation in price associated with bundling is taken into account.[23] Third, Table B1 shows how the share of treated drugs in the bundle changes after the vertical integration. After the VI, in auctions, where VI distributors participate, the share of treated drugs in the bundle increases less compared to the auctions where VI distributors do not participate. It means that public buyers do not deliberately give an advantage to VI distributors via the higher share of treated drugs.[24] Moreover, the share of drugs in the bundle, where VI producer is a single one or among few others, increases little after VI – by 0.17% and 0.54%, respectively. That is, in the markets where VI distributors can have a cost advantage and VI producers can exercise market power, there is a little increase of demand after the vertical integration.

I use OLS/2SLS to estimate equations (1) and (2) without/with control for the *Number of Applicant*. Clustering at a buyer level takes into account potential correlation of error terms.

4.2 Results

Table 3 shows the effect of VI on prices with respect to equations (1) and (2) in auctions, where VI distributors participate. Column 1 and 3 of Panel A shows that, on average vertical integration reduces prices of drugs by 1.5% - 1.7%, i.e. the average effect is pro-competitive. Nevertheless, the effect is highly heterogeneous over the number of producers of drug specifications.

When VI producer is a single one, price increases by 11.4% after the vertical integration if I do not control for the *Number of applicants* (Column 2). After the control for the *Number of applicants*, this effect disappears (Column 4).[25] It suggests that the anti-competitive effect of VI on prices for a single producer case happens due to the indirect effect of vertical integration on prices (reduction of downstream competition), but not because of the direct effect (raising rivals' cost and efficiency gain).

When VI producer is among few other producers, price-per-unit increases by 12.8-13.5%, after the vertical integration (Columns 2 and 4), and control for the *Number of applicants* does not substantially affect the magnitude of the impact. Therefore, it suggests that the anticompetitive

[23] One can alternatively control for drug concentration index, like HHI (see Table 2), instead of the number of drug specifications. It does not change the results.

[24] One can also interpret this as VI distributors do not deliberately participate in auctions with a higher share of treated drugs.

[25] Panel B of Table 3 shows results of the first stage. F statistics for the joint significance of the instruments indicate that instruments are relevant in both specifications (Staiger and Stock (1997)).

effect of VI on prices is due to the direct VI effect on price (raising rivals' cost) but not due to the indirect effect (downstream competition restriction).

When VI producer is among many other producers, price-per-unit decreases by 1.6%-1.8%, after the vertical integration (Columns 2 and 4), and there is no additional impact of the *Number of applicants*. This pro-competitive VI effect suggests that the efficiency effect dominates when the number of producers is large.

I use the sample of auctions, where VI distributors do not participate as a placebo test of the VI effect. In these auctions, the VI producers act as independent firms for bidders even after the vertical integration. Table 4 shows the results. Columns 1 and 3 show the reduction of prices after the VI. There is no VI effect on prices if the upstream market is monopolized or concentrated (Columns 2, 4). For competitive markets, VI reduces prices by 3.4%. These findings confirm that VI producers only exercise market power in concentrated markets if the VI distributor participates in the auction. The price reduction in the case of many producers can be explained by the fact that buyers react to the vertical integration and set the lower reserve price.

The crucial assumption behind the DID results discussed above is the presence of parallel pre-trends before the VI events. Figures B1 and B2 of Appendix show the results of event study design. Prices of the treatment and control group can be seen parallel before the treatment.

Table 3: Effect of VI on prices – VI distributors are participants

	Panel A: Log of price-per-unit of drug			
	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)
ATT	−0.017***		−0.015**	
	(0.006)		(0.006)	
ATT (1 producer)		0.114*		0.056
		(0.065)		(0.075)
ATT (2-4 producers)		0.135**		0.128**
		(0.055)		(0.055)
ATT (at least 5 producers)		−0.018***		−0.016***
		(0.006)		(0.006)
Num. of applicants			−0.092***	−0.092***
			(0.009)	(0.009)
# drug spec. FE	850	850	850	850
Observations	123,074	123,074	122,971	122,971
R^2	0.955	0.955	0.953	0.953
	Panel B: Number of applicants			
	(1)	(2)	(3)	(4)
Share of treated drugs			0.009***	0.009***
			(0.001)	(0.001)
Share of treated drugs∗Post VI			−0.003***	−0.003***
			(0.001)	(0.001)
F statistics			144.78	144.89

*p<0.1; **p<0.05; ***p<0.01

Note. Table shows the estimates of Equations (1) (Columns 1, 3) and (2) (Columns 2, 4) at the drug-level. The sample includes auctions, where VI distributors participate. Panel A shows OLS (Columns 1, 2) and 2SLS (Columns 3, 4) estimates. Panel B shows the results of the first stage for 2SLS. All models control for: quantity percentile FE (bin width of 20%), number of drug specifications, contract duration, an indicator if procurement is centralized, FE on drug specifications, year-quarters, ATC3-years, regions, and suppliers. Errors are clustered at buyer levels. Full output is presented in Table B2 of Appendix.

Table 4: Effect of VI on prices – VI distributor does not participate in auction

	Panel A: Log of price per unit of drug			
	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)
ATT	−0.033**		−0.032*	
	(0.017)		(0.017)	
ATT (1 producer)		−0.065		−0.070
		(0.047)		(0.048)
ATT (2-4 producers)		0.028		0.025
		(0.026)		(0.025)
ATT (at least 5 producers)		−0.034**		−0.033*
		(0.017)		(0.017)
Num. of applicants			−0.043**	−0.043**
			(0.020)	(0.020)
Drug spec. FE	1242	1242	1242	1242
Observations	1,909,394	1,909,394	1,905,849	1,905,849
R^2	0.962	0.962	0.963	0.963
	Panel B: Number of applicants			
			(1)	(2)
Share of treated drugs			0.008***	0.008***
			(0.001)	(0.001)
Share of treated drugs ∗ Post VI			−0.0002	−0.0002
			(0.001)	(0.001)
F statistics			64	64

*p<0.1; **p<0.05; ***p<0.01

Note. Table shows the estimates of Equations (1) (Columns 1, 3) and (2) (Columns 2, 4) at the drug-level. Sample includes auctions, where VI distributors do not participate. Panel A shows OLS (Columns 1, 2) and 2SLS (Columns 3, 4) estimates. Panel B shows results of the first-stage for 2SLS. All models control for: quantity percentile FE (bin width of 20%), the number of drug specifications, contract duration, an indicator if procurement is centralized, FE on drug specifications, year-quarters, ATC3-years, regions, suppliers. Errors are two-way clustered at buyer and drug specification level. Full output is in Table B3 of Appendix.

4.3 Robustness check

This section provides robustness checks of the main results for the sample of auctions, where VI distributors participate. First, since vertical integration events occur at different times, I follow the modern staggered DID literature and implement the stack regression approach. Second, I use an alternative definition for markets by introducing geographical division. Third, I propose an alternative instrument for the *Number of applicants*. Finally, I introduce joint buyer-supplier fixed effects to take into account favouritism and corruption issues in contract allocation. All the changes do not affect the main findings.

The VI events occur in different moments. This raises a potential problem that already treated become control for not-yet treated observations (Callaway and Sant'Anna (2020), Goodman-Bacon (2021)). The literature proposes different approaches, and I follow the stack-regression design (Cengiz et al. (2019)) as it allows to have treatments of different intensities. For each VI event, I choose the treatment and control group as in the main approach, where the control group includes never-treated observation only. For each event-specific dataset – an element of the stack – I introduce the relative time with respect to the treatment, and the treatment happens at time zero (see details in Baker et al. (2021)). I combine all the event-specific datasets in one stack of data and implement regressions (1) and (2) putting year-quarter-stack FE instead of year-quarter FE (λ_t), keeping the rest of the estimation approach. Table C1 of Appendix shows that the results of stack regression are similar to the main ones.

The second robustness check deals with the market definition. So far, a market is equivalent to a drug specification – a combination of active ingredient and dosage. It assumes that all producers work at the national level without any geographical specialization. Such an approach corresponds to the regulatory perspective (see footnote 11 for details), but some producers may not supply their drug to all Russian regions. In this case, without geographical division, I overestimate the upstream competition. That is, for a fixed drug specification, the set of brands available for a buyer may be narrower than the set of national brands with this drug specification. In this robustness check, I define a market as a combination of drug specification and the Western-Eastern location of public buyers.[26] The number of producers for each market is calculated as the number of distinct producers manufacturing brands ever supplied in this market in my data. Figure C1 of Appendix shows the distribution of the number of producers by markets. There

[26] All public buyers located on the west of the Ural mountains are in the Western location.

are 64 monopolized markets by VI producers and 82 markets with 2–4 producers. Table C2 shows results of estimation. Columns 2 shows that the VI effect on prices increases a little for monopolized markets and decreases a little for concentrated markets (2-4 producers) compared to the main result (Column 2 of Table 3). Column 4 of Table C2 confirms that the price increase in monopolized markets is due to the indirect VI effect because control for the *Number of applicants* mitigates the effect. Similar to the main results, control for the *Number of applicants* does not change the effect of VI for concentrated markets. All in all, the results of this robustness check are similar to the main ones.

The third robustness check is devoted to the instrument for the *Number of applicants*. Identification section highlights three reasons for endogeneity of the *Number of applicants* in Equations (1) and (2): (i) potential foreclosure, (ii) entry cost, (iii) collusion of bidders. The main instruments *Share of treated drugs* in the bundle and its interaction with post VI event can predict the variation in *Number of applicants* due to the first reason. To cope with the second reason, I implement the standard approach in the literature. Specifically, I use number of potential bidders as an instrument for the number of bidders (De Silva et al. (2008), De Silva et al. (2009), Krasnokutskaya and Seim (2011), Athey et al. (2011), Athey et al. (2013)). Following Athey et al. (2013), I use the maximum number of applicants within clusters, defined as "active ingredient-region-year", as a measure of the potential number of applicants.[27] Note potential number of applicants can also be helpful to solve the endogeneity generated by the third reason, as a higher number of potential applicants would likely result in a higher number of independent groups. Table C3 of Appendix shows the results with the original instruments (Columns 1-2), alternative instrument (Columns 3-4) and their combination (Columns 5-6). The combination of instruments includes all three instruments in the first stage. Results of ATT estimates for different upstream market structures from all these IV strategies are similar.

The fourth robustness check considers the issue of favouritism and corruption in public contracts allocation.[28] I introduce joined buyer-supplier fixed effects in Equations (1) and (2) to control for potential time-invariant favouritism in contract allocation by buyers to suppliers. The estimation

[27]To construct clusters as "active ingredient-region-year" I consider only e-auctions with only one active ingredient in the bundle. There are 71610 such clusters, corresponding to 443 active ingredients, 86 regions, six years. Alternative definition of clusters as "active ingredient-region" gives 21992 different clusters, but the estimation results are similar.

[28]See a corruption investigation about the head of the Biotech – pharma distributor that had divestiture with producer Biosintez in December 2016 (https://thebell.io/en/fsb-accused-of-stealing-pharma-business-after-arrest-of-billionaire-2))

results are shown in Table C4 of Appendix. The results coincide with the main findings regarding the VI effect on prices.

5 Theoretical model

This section proposes a theoretical model of procurement auction in an industry with vertical structure. Equilibrium analysis of this game rationalizes the reduced-form evidence and is a foundation for the structural estimation of producer and distributor costs.

5.1 Players, timing and cost structure

The buyer announces descending procurement auction to purchase a unit of drug. The public reserve price r is the buyer willingness to pay. The unit of drug is indivisible and can be supplied by at most one distributor. There are N upstream risk-neutral producers of the drug $\{P_i\}_{i=1}^N$ and M downstream risk-neutral distributors $\{D_j\}_{j=1}^M$ are going to participate in the auction to supply the drug to the buyer. Without loss of generality, I assume that producers do not participate directly in the auction.[29] The distributors do not own the drug but have to negotiate its price with the producers before bidding. The timing of the game is the following.

Time 1: negotiation stage. The producers observe independent private production costs $(c_i)_{i=1}^N$. All distributors negotiate input prices with all the producers and accept the minimal price. The profile of input(negotiated) prices is $(p_j)_{j=1}^M$. There is no trade at this stage, but commitment about the input prices.

Time 2: bidding stage. The distributors observe independent private delivery costs $(d_j)_{j=1}^M$. The total cost tc_j of distributor j is sum of input price p_j and delivery cost $tc_j = p_j + d_j$. The distributors participate in the descending procurement auction organized by the buyer. The winning distributor trades with the producer at the committed price specified at the negotiation stage and supplies the drug.

I consider two scenarios: (i) *Vertical separation* (VS) scenario when all producers and distributors are independent firms, (ii) *Vertical integration* (VI) scenario when the first producer P_1 is vertically integrated with the first distributor D_1 and other producers and distributors are independent. In VI scenario I define $\{P_i\}_{i=2}^N$ as *rival producers* and $\{D_j\}_{j=2}^M$ as *rival distributors*.

[29] Participation of a producer in the auction is equivalent to the vertical integration scenario between producer and distributor, which I discuss below.

I model the negotiation process at Time 1 as follows. If a producer is unique ($N = 1$), she sets an input price p_j to each distributor j.[30] If there are several producers of the drug ($N > 1$), then each distributor, simultaneously with other distributors, solicits bids from all the producers via an internal descending auction.[31] In the VI scenario, in addition to the negotiation, the VI distributor has a right to get the drug internally from the VI producer at the cost $p_1 = c_1 - \delta$, where $\delta \geq 0$ is an exogenous *synergy effect* of the vertical integration. One can think of positive δ as a transaction cost, which is included in c_1 if P_1 interacts with an external distributor, but it is absent when P_1 interacts internally with D_1. Parameter δ is common knowledge.

I assume that producers and distributors are symmetric in VS scenario. Specifically, random variables c_i ($i \in \{1, \ldots, N\}$) are independent draws from a continuously differentiable distribution $F(x)$ with support $[\underline{c}, \overline{c}]$ and density $f(x)$. Similarly, d_j ($j \in \{1, \ldots, M\}$) are independent draws from a continuously differentiable log-concave distribution $G(x)$ with support $[\underline{d}, \overline{d}]$ and density $g(x)$ that is positive on the interior of the support.[32] The goal of analysis is to compare ex-ante expected buyer payments under VS and VI scenarios, denoted as $\mathbf{E}p^{vs}$ and $\mathbf{E}p^{vi}$, respectively.

5.2 Single producer case

I start with the analysis of a single producer case ($N = 1$) and denote the production cost of a single producer as $c \equiv c_1$. For this case, following the procurement regulation of pharmaceuticals, I assume that the government regulates the producer prices. That is, at the negotiation stage, the producer cannot set the price above $\overline{p}$ to any distributor, and $\overline{p}$ is sufficiently smaller than the

[30] For simplicity, I assume that distributors have zero bargaining power when the producer is unique, though the main result (Proposition 1) holds even if one assumes Nash bargaining setting and positive bargaining power of distributors that does not change after the vertical integration.

[31] Each distributor negotiates prices with potentially many producers but finally trades with just one of them. Moreover, the production cost is private information of producers. Therefore, I cannot use model of Nash-in-Nash bargaining proposed by Horn and Wolinsky (1988) and extended in Crawford and Yurukoglu (2012), Gowrisankaran et al. (2015), Crawford et al. (2018), Collard-Wexler et al. (2019), Lee et al. (2021)), as it requires complete information at the negotiation stage. An alternative way to model negotiation process is to use auctions (Bulow and Klemperer (1996), Thomas and Wilson (2002), Thomas and Wilson (2005), Klemperer (2007), Ho (2009), Miller (2014), Allen et al. (2019), Loertscher and Marx (2019), Kotowski and Leister (2019), Loertscher and Riordan (2019), Loertscher and Marx (2020)). Descending open auction is a relevant model if one assumes that each distributor can play producers off against each other, up to the point at which the price offered by the lowest cost producer cannot be profitably beaten by the other producers – bargaining leverage of distributor. At that point, the distributor has no more bargaining leverage, and the negotiation ends.

[32] The distribution F is log-concave if $ln(F(x))$ is a concave function of x or, equivalently, if $\frac{F(x)}{f(x)}$ is a non-decreasing function of x (Bagnoli and Bergstrom (2005)). This is standard assumption in the monopoly theory and mechanism design literature (Myerson and Satterthwaite (1983), Maskin and Riley (1984), Riordan and Sappington (1989)) and I am going to use it in a similar setting.

reserve price r. Specifically, I impose the following assumption.

Assumption 1. *Input prices at the negotiation stage cannot exceed $\overline{p}$, where $\overline{p} \leq p_M^*(c) < r$ and $p_M^*(c)$ is a solution for the upstream monopoly profit maximization problem given the production cost c and M downstream distributors:*

$$\max_p (p - c)\, \mathbf{P}\left(p + \min(d_1, \ldots, d_M) \leq r\right) \tag{3}$$

The first term of (3) is the profit of the monopolist, who sets the same input prices to all the distributors, given the trade occurs, and the second term is the probability that trade occurs. Assumption 1 implies that upstream monopolist cannot set the price too close to the reserve price even if she can guarantee at least one bidder in the auction. It also implies that the buyer should not set the reserve price too close to $\overline{p}$, so that there are enough incentives for distributors to enter the procurement auction.[33] Appendix D shows that $p_M^*(c)$ is non-decreasing in c and increasing in M. The following proposition characterizes the expected buyer payment under VS and VI scenarios.

Proposition 1. *Let Assumption 1 be satisfied, and assume the single producer commits to work with all the distributors. Then*

i. If synergy effect is zero ($\delta = 0$) then $\mathbf{E}p^{vi} = \mathbf{E}p^{vs}$.

ii. If synergy effect is positive ($\delta > 0$) then $\mathbf{E}p^{vi} < \mathbf{E}p^{vs}$.

In both cases P_1 sets prices at the negotiation stage at the level $\overline{p}$.

See details of the proof in Appendix D. Intuition of Proposition 1 is the following. The single producer in the VS scenario is willing to set the price at $p_M^*(c)$ and in the VI scenario – even above. However, due to the price regulation, she sets the price at $\overline{p}$ to all the distributors, except for D_1 in the VI scenario. Therefore, the vertical integration does not lead to higher input prices for rival distributors in the VI scenario compared to the VS scenario. Moreover, in the VI scenario, if D_1 enters the auction together with a rival distributor, he has incentives to behave like an independent firm because the single producer will get $\overline{p}$ irrespective of who wins the auction. Thus, the competitive advantage D_1 receives by getting the product at the production cost is not

[33] If the reserve price is binding and the auction failed to attract at least one distributor, the buyer has to re-announce the auction at a higher reserve price, so we turn to the case $\overline{p} \ll r$.

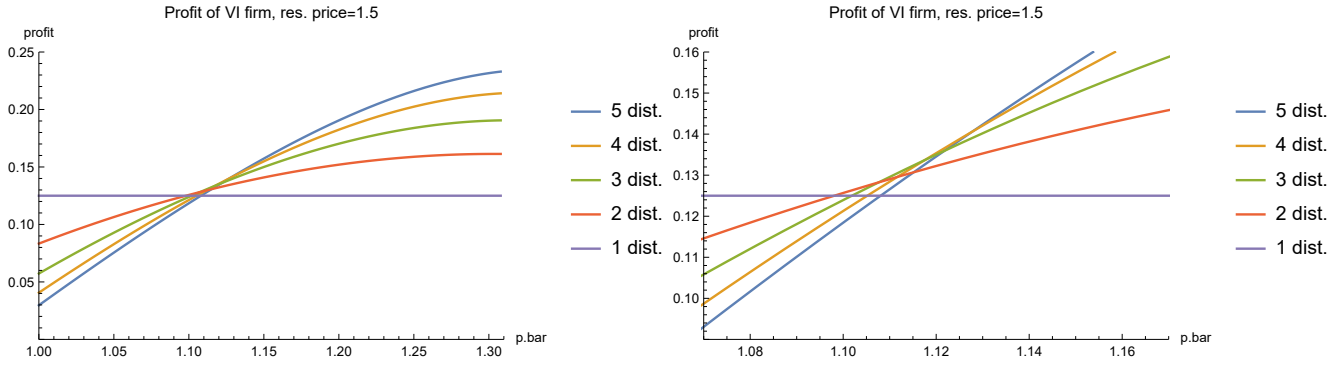
passed through to the buyer without synergy effect. However, if the synergy effect is positive, it is partially passed through to the buyer.

This intuition also emphasizes the importance of Assumption 1. If one relaxes Assumption 1, then in the VS scenario P_1 sets the input price equal to $p_M^*(c)$ and in the VI scenario P_1 sets the input price above $p_M^*(c)$ to rival distributors, which increase the buyer payment.

Remark 1. *If synergy effect is zero* ($\delta = 0$) *and Assumption 1 fails then* $\mathbf{E}p^{vi} > \mathbf{E}p^{vs}$.

Note the importance of commitment assumption in Proposition 1, i.e. P_1 commits not to foreclose (exclude) any downstream distributor.[34] Figure 2 shows that if $\bar{p}$ is small enough, then the VI producer has incentives to foreclose(exclude) one or more rival distributors to increase the expected profit (Panel (a)). However, it is not always beneficial for the VI producer to foreclose all rival distributors (Panel (b)), but only some of them. This result is in line with literature findings emphasizing that the inability of the upstream integrated monopolist to extract sufficient profit from downstream rivals generate foreclose incentives (Rey et al. (2014), Fumagalli et al. (2018), Fumagalli and Motta (2020)).[35]

Figure 2: Profit of VI firm for different number of distributors



(a) Full domain $\bar{p} \in [1, p_5^*(1)]$ **(b)** Subset of $[1, p_5^*(1)]$ for $\bar{p}$

Note. Figure shows the simulation results if $c = 1$, $d_j \sim U[0,1]$, $M = 5$, $r = 1.5$, $\delta = 0$. X-axis shows $\bar{p}$. Y-axis shows the expected profit of VI firm. Panel (a) has domain $[1, p_5^*(1)]$ and Panel (b) is a zoom in a domain subset.

Let me summarize the model conclusions for the case of a single producer. If there is no foreclosure(exclusion) of any distributor from the deal, then VI is never anti-competitive for the buyer.

[34] Whether this assumption holds for a specific setting depends on the antitrust regulation. For example, one can think of a regulation in which a single producer is obliged to sell to any certified distributor at a price that does not exceed the posted price.

[35] In a separate study, I show that the integrated producer has no foreclosure incentives in a setting without price regulation. Moreover, in a more general setting in which the integrated producer knows the distribution cost of the integrated distributor at the negotiation stage, all the results mentioned above hold, including Proposition 1 and Remark 1.

Moreover, if the synergy effect is positive, then VI is pro-competitive for the buyer. However, foreclosure is harmful to the buyer and under some conditions, it is even beneficial for the integrated firms. These findings rationalize the reduced-form evidence from Table 3 for the case of a single producer. When downstream competition is fixed via the control for the *Number of applicants*, the vertical integration has no direct effect on prices. However, the VI has an indirect impact on prices via the change in the downstream competition.

5.3 Multiple producers case

Now consider the case with several upstream producers ($N > 1$). Due to competition at the upstream and downstream levels, I assume that the reserve price is not binding.[36] Appendix D shows, the total cost of distributor D_j in the VS scenario has the form

$$tc_j = c_2^{(N)} + d_j \quad (j \in \{1, \dots M\}), \tag{4}$$

where $c_2^{(N)}$ is the second-lowest producer cost of the profile $(c_1, c_2, \dots c_N)$. In the VI scenario, D_1 becomes asymmetric with respect to the rival distributors because of double markup elimination and the synergy effect δ. Moreover, P_1 may have incentives for RRC, so the total costs of distributors have the following form:

$$\begin{aligned} tc_1 &= min\left(c_2^{(N-1)}, c_1 - \delta\right) + d_1; \\ tc_j &= c_2^{(N)}(\mu) - \rho + d_j \quad (j \in \{2, \dots, M\}), \end{aligned} \tag{5}$$

where $c_2^{(N-1)}$ is the second-lowest value of the profile $(c_2, \dots c_N)$ and $c_2^{(N)}(\mu)$ is the second-lowest value of the profile $(c_1 + \mu, c_2, \dots c_N)$. Here μ is a strategic markup P_1 sets to the rival distributors, which characterizes the RRC effect, and ρ is a strategic rebate the lowest cost (*strongest*) rival producer gives to rival distributors anticipating the RRC effect of P_1. Appendix D defines the equilibrium strategies μ and ρ of P_1 and strongest rival producer formally, and it shows that other players have weakly dominant strategies. It turns out that without imposing additional assumptions on distributions of producers and distributors costs, the closed-form solution of the equilibrium is problematic, and the approach via the first-order condition is not feasible because of

[36] If $N > 1$, without loss of generality, one can assume that $\bar{c}$ is equal to the regulated price $\bar{p}$ because any producer has to offer a price below $\bar{c}$.

the possibility of corner solutions. Therefore, only a numerical solution is feasible. Nevertheless, this model exhibits a remarkable result when N is large enough.

Proposition 2. *Assume that non-strongest rival producers and all distributors follow their weakly dominant strategies. Then for any strategies $\mu \geq 0$ and $\rho \geq 0$, the following holds:*

i. if synergy effect is zero ($\delta = 0$) then $\lim_{N\to\infty} \mathbf{E}p^{vi} - \mathbf{E}p^{vs} = 0$;

ii. if synergy effect is positive ($\delta > 0$) then $\lim_{N\to\infty} \mathbf{E}p^{vi} - \mathbf{E}p^{vs} < 0$.

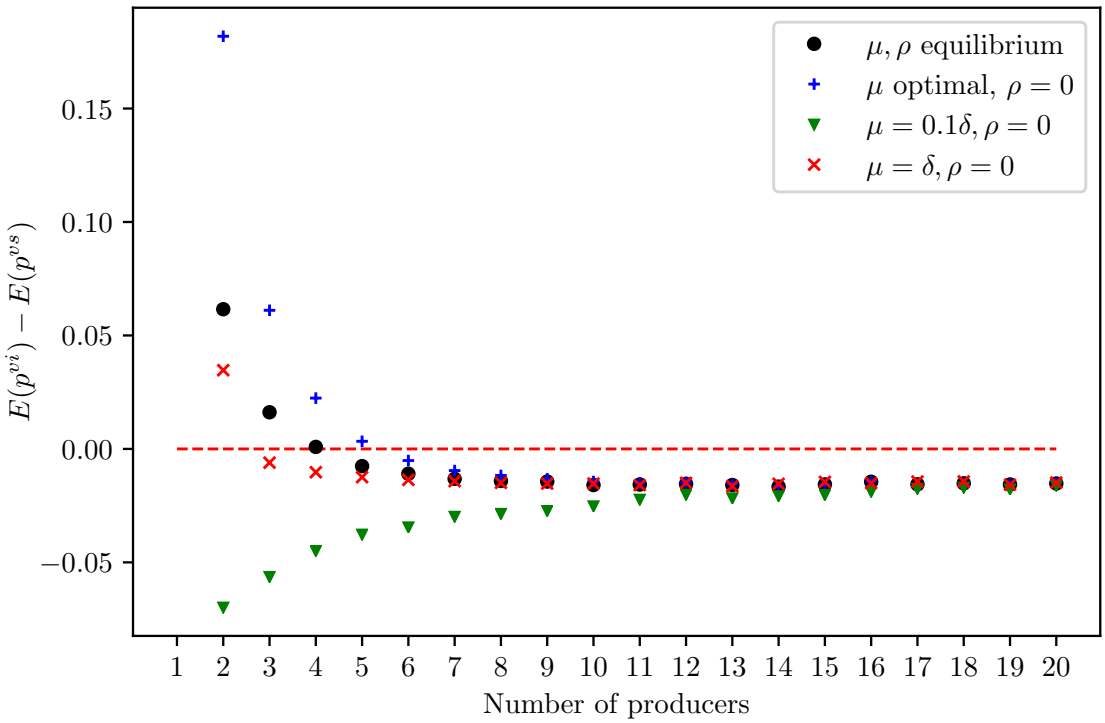
See proof in Appendix D. The intuition of Proposition 2 is the following. When the number of producers is large, the RRC effect is negligible because several rival producers can likely undercut the offer of P_1 at the negotiation stage, so the vertical integration cannot harm the buyer.[37] At the same time, the positive synergy effect $\delta > 0$ creates an asymmetry between D_1 and rival distributors. This cost advantage helps D_1 to offer the lower bid in the procurement auction leading to the lower buyer payment.

Figure 3 demonstrates the outcomes of the game for uniformly distributed producer and distributor costs and synergy effect $\delta = 0.25$. If the number of producers is large enough ($N \geq 6$), the difference of the expected buyer payment in the VI and VS scenarios is negative irrespective of strategies μ and ρ. In the equilibrium, the VI is pro-competitive if $N \geq 5$. However, if the number of producers is small ($N = 2$ or $N = 3$), then the VI is anti-competitive in the equilibrium as it increases the expected buyer payment.

Propositions 2 rationalizes the reduced-form evidence from Table 3 for the case with many producers. The simulation shows that for the case with a few producers, the vertical integration can be anti-competitive. However, the actual effect depends on the costs distributions and synergy effect, which is merely the empirical issue. Structural estimation of producer and distributor costs and simulations of vertical mergers with different synergy effects help to answer this issue.

[37] Notice that foreclosure(exclusion) of rival distributors cannot create an additional effect, since it is equivalent for P_1 to offer $\bar{c}$ at Stage 1. Rival distributors would reject this offer as rival producers can undercut it.

Figure 3: Simulation of $\mathbf{E}p^{vi} - \mathbf{E}p^{vs}$ for different number of producers



Note. This figure shows a result of simulation of $\mathbf{E}p^{vi} - \mathbf{E}p^{vs}$ for $m = 3$, $c_i \sim U[3, 4]$, $d_j \sim U[1, 2]$. X-axis shows the number of upstream producers, Y-axis shows the difference in ex-ante expected buyer payment under VI and VS scenarios. The synergy effect $\delta = 0.25$. The black dots show outcomes for equilibrium strategies μ, ρ. Blue crosses show outcomes for optimal μ given $\rho = 0$. Cases $\mu = 0.1\delta$ and $\mu = \delta$ assume that strategy $\mu(c_1)$ is constant.

6 Structural estimation

In this section, I use the VS scenario of the model with multiple producers and propose an identification and estimation strategies of producer and distributor cost distributions from the auction data. Then, taking estimated costs distributions, I simulate vertical mergers under different conditions and derive policy implications for the merger approval.

6.1 Identification

In the model with multiple producers and the VS scenario, the total distributor costs have the form (4). To fit the data, I extend this form by introducing the observed heterogeneity in the linear-additive form (Haile et al. (2003), Larsen (2021)), so the total cost of distributor D_j ($j \in \{1, \dots, M\}$) in the auction a has the following structure:

$$tc_{j,a} = \underbrace{c_{2,a}^{(N)}}_{common\,term} + \underbrace{d_{j,a}}_{private\,value} + \underbrace{\beta \mathbf{X_a}}_{observed\,heterogen.}. \tag{6}$$

Here $c_{2,a}^{(N)}$ is a negotiated price and it equals to the second-lowest producer costs, $d_{j,a}$ is a distribution cost, and X_a is the observed heterogeneity affecting the total cost via parameters β. In the data, I observe bids from the descending procurement auctions with the public reserve price r_a. With respect to econometrician $c_{2,a}^{(N)}$ is an unobserved heterogeneity. My approach extends the literature on the identification in auctions with unobserved heterogeneity (Krasnokutskaya (2011), Freyberger and Larsen (2017), Larsen (2021)) by rationalizing the unobserved heterogeneity as the equilibrium negotiation price at the upstream level. [38] Following this literature, I impose standard assumptions on bidders behaviour and cost distributions.

Assumption 2. ***(No jumping.)*** *In the descending auction, all bidders follow the weakly dominant strategy of bidding up to their total cost.*

Assumption 3. ***(Independence.)*** *(i) Producer costs $(c_{i,a})_{i=1}^{N}$, distributor costs $(d_{j,a})_{j=1}^{M}$ and the observed heterogeneity $\mathbf{X_a}$ are mutually independent; (ii) Conditional on the observed heterogeneity, auctions are independent.*

Assumption 4. ***(Distributions.)*** *(i) Producer costs are normalized to satisfy $\mathbf{E}\left(c_{2,a}^{(N)}\right) = 0$; (ii) Characteristic functions of producer and distributor costs have isolated zeros.*

Assumption 5. ***(Non-binding reserve price.)*** *The reserve price can be non-binding, i.e. $\mathbf{P}(\overline{c} + \overline{d} \leq r_a - \beta \mathbf{X_a}) > 0$.*

Assumption 2 guarantees that the observed bids reveal the unobserved order statistics of total costs, so the structural approach is feasible.[39] Assumption 3 is necessary to separately identify the distributions of common input price and idiosyncratic distribution cost. Assumption 4 is technical, and it imposes location normalization. Without this assumption, the cost distributions are identified up to the constant shift. One can add a constant to distribution cost and subtract the same constant from the production cost having the same total costs and equilibrium bids.

[38] The identification can also incorporate the unobserved heterogeneity per se, as Appendix E shows. Nevertheless, in the application for procurement of standardized goods, such as drugs, the unobserved heterogeneity is excessive because econometrician observes all the characteristics of auction and drug.

[39] In the context of Russian procurement, the descending auctions are implemented at the electronic platforms, and each next bid has to propose a rebate no less than 0.5% of the reserve price from the current bid.

Assumption 5 guarantees that the full support of the producer and distributor cost distributions can be identified; otherwise, only truncated distribution is identified. It also guarantees that in some auctions, all potential distributors can enter so that the potential number of bidders can be inferred from these auctions.

Proposition 3. *If Assumptions 2 - 5 hold, then the producer and distributor cost distributions and observed heterogeneity parameters are identified.*

Appendix E provides the formal proof. The idea of identification is the following. First, to match the additive form of total cost (6) with constraints that bids should be non-negative, I make the log-transformation of bids and reserve price and work with them as if they are actual bids and reserve price.[40] Second, I implement the "homogenization" of auctions by taking the residuals of an OLS regression of auction bids and reserve price on the observed heterogeneity. Third, the winning and second-lowest bids help identify the distributions of negotiated price and order statistics of distribution costs. To get the intuition of this step, denote by $b_{k,a}^{(m)}$ the kth lowest homogenized bid in auction a with m observed bidders. Then the expectation and variance of negotiated prices and order statistics of distribution cost can be identified as follows:

$$c_{2,a}^{(N)} : E\left(c_{2,a}^{(N)}\right) = 0, \quad Var\left(c_{2,a}^{(N)}\right) = cov\left(b_{1,a}^{(m)}, b_{2,a}^{(m)}\right); \tag{7}$$

$$d_{k,a}^{(M)} : E\left(d_{k,a}^{(M)}\right) = E\left(b_{k,a}^{(m)}\right), \quad Var\left(d_{k,a}^{(M)}\right) = Var\left(b_{k,a}^{(m)}\right) - Var\left(c_{2,a}^{(N)}\right), \tag{8}$$

where I use (6) and Assumption 4. Finally, having the distributions of negotiated price and order statistics of distribution costs, I invert them to get the original cost distributions:

$$c_i : F(x) = F^{-1}_{Beta(2,N-1)}\left(F_{c_2^{(N)}}(x)\right) \tag{9}$$

$$d_j : G(x) = F^{-1}_{Beta(k,M+1-k)}\left(G_{d_k^{(M)}}(x)\right) \tag{10}$$

6.2 Estimation strategy

I allow for the reserve price to be binding, i.e. distributor D_j enters the auction a if $tc_{j,a} \leq r_a$. It makes the auction entry endogenous, so the unobserved potential number of bidders M can differ from the observed number of bidders m. Following Assumption 5, I estimate the potential

[40] Appendix E shows that log-transformation of bids having multiplicative form makes it equivalent to the additive form with the logarithm of bids.

number of bidders M in the auction as the maximal number of bidders among all auctions with one active ingredient in the bundle within the cluster defined as "active ingredient-region-year". Then I choose a specific sample of auctions, satisfying the following conditions: (i) only two vertically separated producers are in the market; (ii) producers do not bid directly in these auctions; (iii) auction bundle includes only one drug specification; (iv) auction reserve price is above 2M RUB (31K USD). Conditions (i) and (ii) guarantee that the auction satisfies the VS scenario and that bidders are distributors. Moreover, the presence of only two producers mitigates the concern that, in reality, the distributors do not negotiate with all the producers. [41] Condition (iii) helps to disregard the potential confounding effect of bundling and enables to analyze bid-per-unit of a drug. Condition (iv) mitigates the issue that distributors can use stored drugs and not re-negotiate with the producers. I keep only drug specifications having at least 500 observations after this filtering procedure. This procedure keeps only three active ingredients *Sunitinib, Sorafenib, Nilotinib* being all of them anti-neoplastic drugs. I estimate the distributions of producer and distributor costs separately for each of these active ingredients.

The estimation procedure starts from calculating the bids-per-unit and reserve price-per-unit of a drug. That is, I divide the final bid for each bidder and the reserve price for a bundle by the quantity of drugs in the bundle. Next, I make log-transformation of bids-per-unit and reserve price-per-unit and consider them as original bids and the reserve price. Next, I "homogenize" these bids and the reserve price to exclude the observed heterogeneity.[42] For homogenized bids and the reserve price, I apply the maximum likelihood approach imposing parametric assumptions.[43] Namely, I assume that producer and distributor costs have normal distributions,[44] i.e. $c_i \sim N(\mu_c, \sigma_c^2)$, $d_i \sim N(\mu_d, \sigma_d^2)$. The likelihood function incorporates the following events (i) observing zero entrants with likelihood $p_0 = \mathbf{P}(m = 0)$; (ii) observing one entrant with likelihood $p_1 = \mathbf{P}(m = 1)$; (iii) observing two entrants and the winning bid x with likelihood $p_2(x) = \mathbf{P}(tc_2^{(M)} = x, m = 2)$; (iii) observing $k \geq 3$ entrants and the winning bid x and the second-lowest bid y with likelihood $p_k(x, y) = \mathbf{P}(tc_2^{(M)} = x, tc_3^{(M)} = y, m = k)$. Appendix E shows how these individual likelihood functions can be expressed via the primitive distributions of producer cost $F(x)$, distributor cost

[41] In my full data, for a fixed drug specification, a distributor supply brands of three producers, on average, and the median is two.

[42] The vector of the observed characteristics is year and buyer region FE, log of quantity units of the drug.

[43] Appendix E shows that semi-parametric approach is also feasible, but it would require more observations for each active ingredient.

[44] Recall that I work with log-transformed bids, so negative realizations of the normal distribution are not an issue. It would be equivalent to assuming log-normal distributions in the multiplicative form of total costs.

$G(x)$, and the number of potential bidders M. The overall log-likelihood function equals to

$$l = \sum_{a:m=0} ln(p_0) + \sum_{a:m=1} ln(p_1) + \sum_{a:m=2} ln(p_2(x_a)) + \sum_{a:m=k\geq 3} ln(p_k(x_a, y_a)) \tag{11}$$

and it is maximized on the set of parameters $(\mu_c, \sigma_c, \mu_d, \sigma_d)$ under the normalization constraint $\mathbf{E}\left(c_2^{(N)}\right) = 0$ imposed by Assumption 4 on these parameters. Standard errors of parameters are estimated via bootstrap with 100 replications.

6.3 Estimation results and simulations

Table 5 shows the estimates from the maximum likelihood. The parameter μ_c is negative because of the normalization Assumption 4. Though the parameters do not have the intuitive interpretation per se, the sum of $\mu_c + \mu_d$ can be interpreted as the logarithm of the unit total cost for a vertically integrated distributor without synergy effect. The coefficient of $ln(quantity)$ in absolute value varies from 0.04% to 0.06% and shows the percentage decrease of total distributor cost when quantity increases by 1%.

Table 5: Parameters of producer and distributor cost distributions

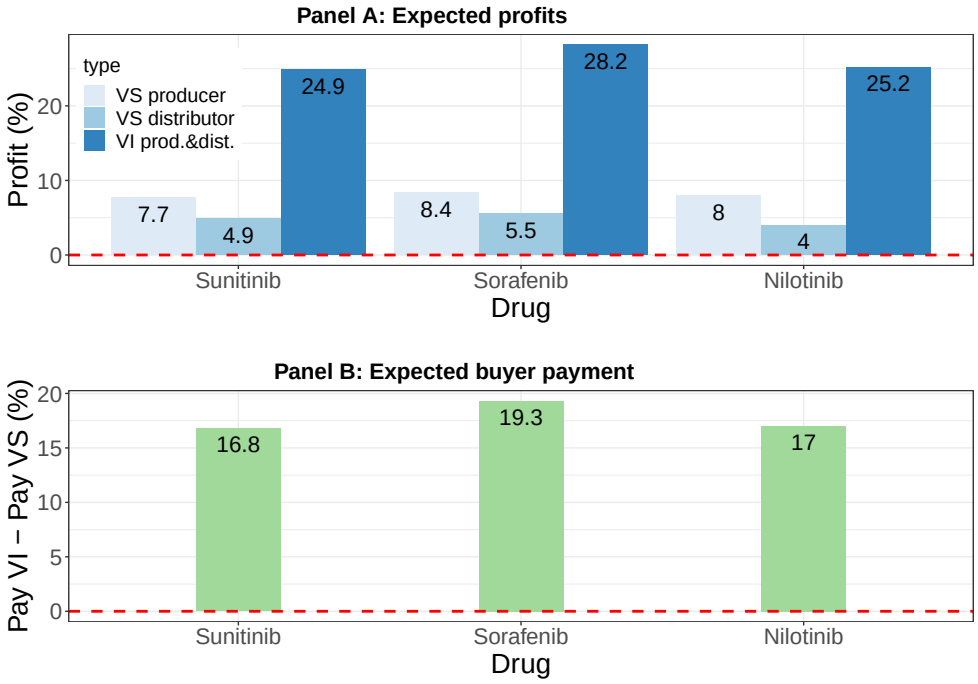
		Sunitinib	Sorafenib	Nilotinib
Producer	μ_c	-0.0749	-0.0846	-0.0775
cost		(0.0456)	(0.0241)	(0.0543)
parameters	σ_c	0.1329	0.1501	0.1374
		(0.0815)	(0.1332)	(0.1009)
Distributor	μ_d	9.1466	7.4769	7.7138
cost		(0.0137)	(0.1386)	(0.0577)
parameters	σ_d	0.1730	0.1959	0.1420
		(0.0935)	(0.0711)	(0.0935)
Observed	ln(quantity)	-0.0512	-0.042	-0.061
heterogeneity		(0.007)	(0.007)	(0.009)
	Regional FE	Y	Y	Y
	Year FE	Y	Y	Y
	Observations	789	730	569
Total cost in log	$\mu_c + \mu_d$	9.0717	7.3923	7.6363
Total cost in RUB	$e^{\mu_c+\mu_d}$	8705	1623	2072

Note. The table shows estimates of expectation and standard deviation for producer and distributor costs, assuming the normal distributions. The observed heterogeneity includes log-quantity of drug units, year and buyer region FE. Bootstraped standard errors are in parentheses.

I use the parameters of the estimated distributions to simulate vertical mergers under different conditions. Figure 4 shows that a merger without synergy effect doubles the profit of the integrated firm compared to the aggregate profit of separated producer and distributor (Panel A). However, such integration harms the public buyer whose expected payment increases by 17%-19% (Panel B). Such an anti-competitive effect happens because the VI producer can raise input prices for rival distributors by limiting the extent of upstream competition. The double markup elimination of VI distributor without synergy effect is not enough to neutralize it. Therefore, the antitrust authority should not approve such vertical mergers.

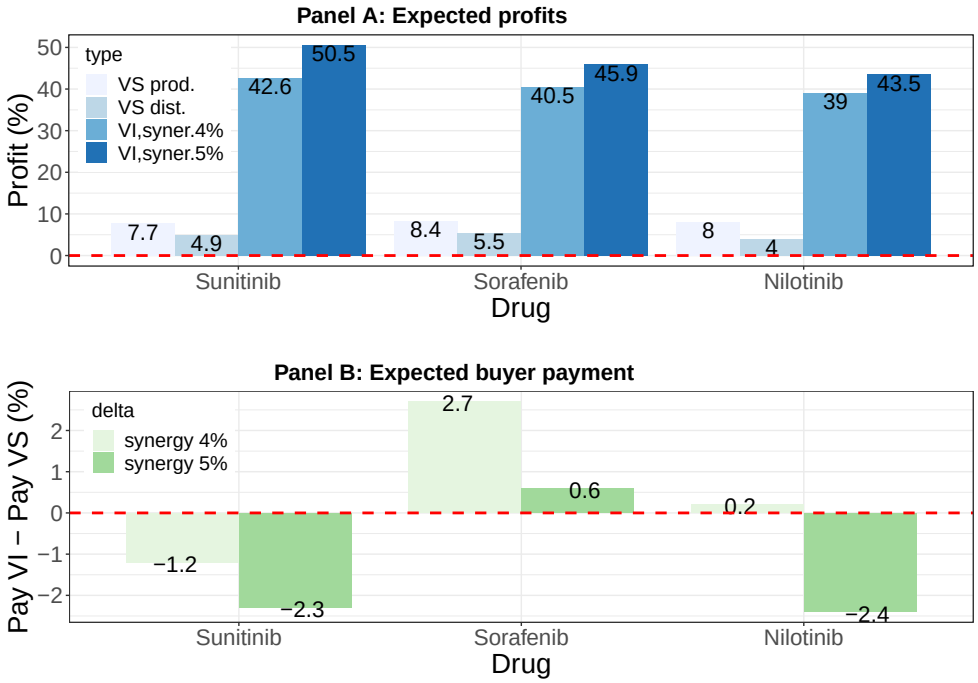
The following simulation quantifies what synergy effect would be sufficient to neutralize the anti-competitive effect of VI. Figure 5 shows that if the synergy effect is from 4% to 5% of the total distributor cost ($\mu_c + \mu_d$ from Table 5), then the expected buyer payments under VS and VI scenarios are almost equal, or the payment under VI scenario is even lower (Panel B). Due to the synergy effect, such a merger is even more profitable for the firms (Panel A).

Figure 4: Simulation of VI without synergy effect



Note. The figure demonstrates the simulation result of a vertical merger without synergy effect for drugs with two producers and three distributors. Panel A shows the producer and distributor's expected profit (as a percentage of their costs) under the VS and VI scenario. Panel B shows the difference in the expected buyer payment under VI and VS scenarios (as a percentage of the expected payment under VS scenario).

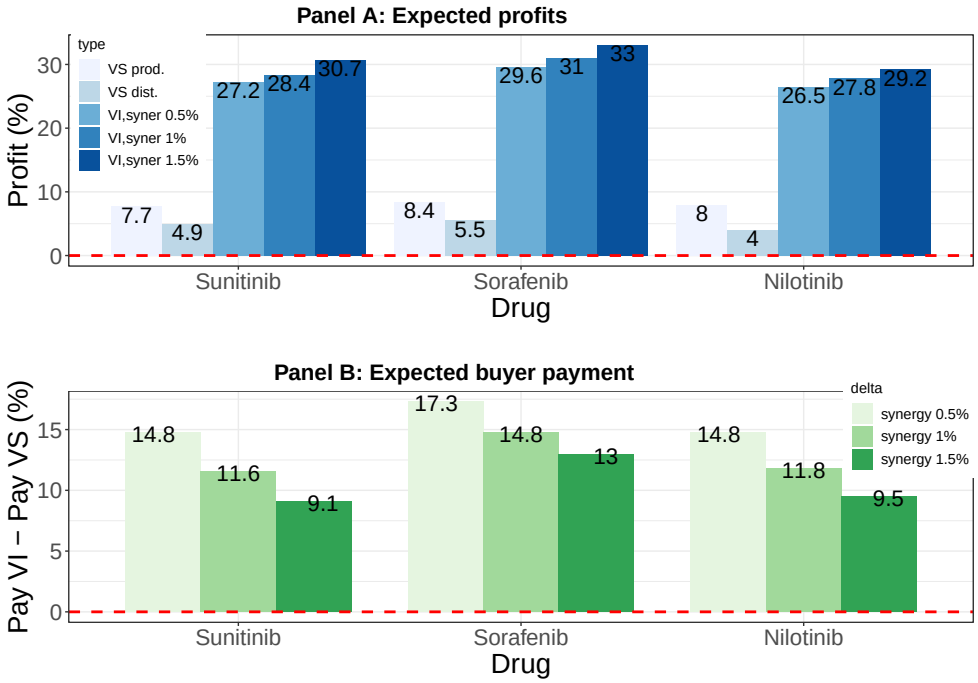
Figure 5: Simulation of VI with synergy effect of 4%-5% of the total costs



Note. The figure demonstrates the simulation of vertical mergers with synergies of 4% and 5% of the total cost ($\mu_c + \mu_d$ of Table 5) for drugs with two producers and three distributors. For more details, see Note of Figure 4.

Next, I estimate what synergy effect would rationalize the reduced-form evidence. I match the change in the expected buyer payment from the VI simulation with DID estimate of the VI effect of 12.8%–13.5% (see Table 3 for 2–4 producers). Figure 6 shows that a merger with synergy from 0.5% to 1.5% of total costs leads to an around 13% increase in the expected buyer payment, suggesting this interval of synergies well explain the average VI effect. Recall that the synergy effect of integration happens because of decreased procurement transaction costs between the integrated producer and distributor. The literature estimates the procurement transaction costs of buyers and suppliers, on average, around 1.4% in the EU (Strand et al. (2011)) and around 1% in Russia (Balaeva et al. (2020)). Noteworthy, the producers–distributors negotiation is a form of internal procurement. Therefore, my estimates of the synergy effect and transaction cost estimates from the literature suggest that the synergy effect of 4% - 5% of vertical integration is challenging.

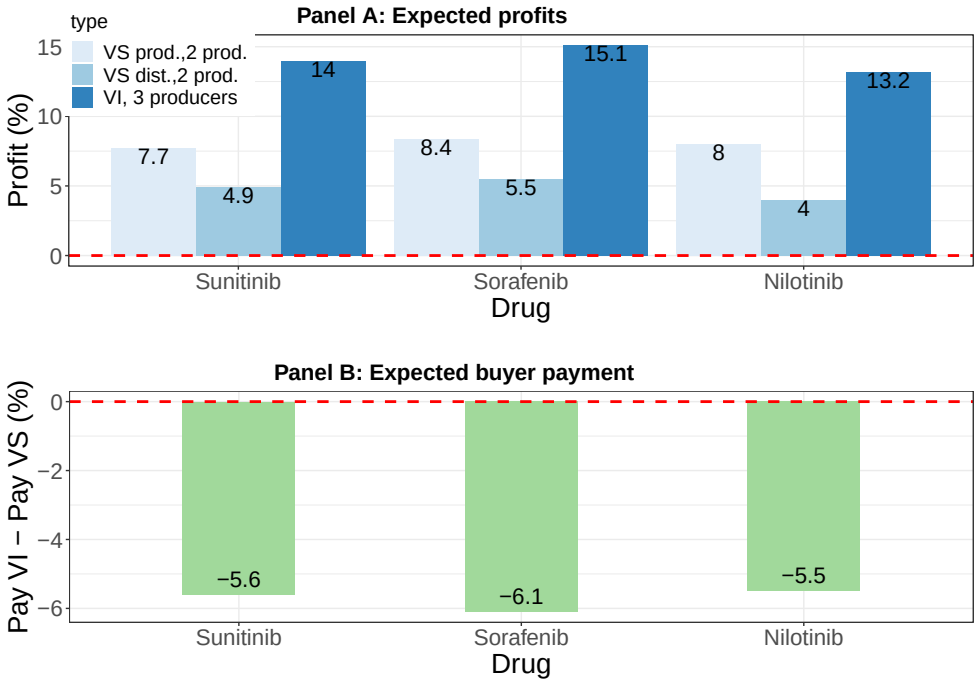
Figure 6: Interval estimates of the synergy effect



Note. The figure demonstrates the simulation of vertical mergers with synergies of 0.5%, 1%, 1.5% of the total cost ($\mu_c + \mu_d$ of Table 5) for drugs with two producers and three distributors. For more details, see Note of Figure 4.

What can be the effective remedies if the synergy effect is not as significant or absent? In the following simulation, I show that the exogenous entry of a third producer is an effective remedy for the vertical merger with 1% synergy. Figure 7 shows the vertical merger simulation with two producers under the VS scenario and three producers under the VI scenario with 1% synergy effect. The buyer payment under the VI scenario with three producers is smaller by around 5.8% compared to the payment under the VS scenario with two producers (Panel B). At the same time, the profit of the integrated firm is higher by 1%-2% than the aggregate profit of producer and distributor in the VS scenario (Panel A). Thus, such a vertical merger with the exogenous entry of a third producer is both pro-competitive for buyers and beneficial for the firms. It suggests that the antitrust authority can approve the vertical merger only if the merging producer sells its production technology to the new independent producer, keeping the production rights but generating the exogenous entry.

Figure 7: Exogenous entry of the third producer under VI scenario



Note. The figure demonstrates the simulation of a vertical merger with 1% synergy of the total cost having two producers in the VS scenario and three producers in the VI scenario. For more details, see Note of Figure 4.

7 Conclusion

The paper studies the competitive effect of vertical integration between pharmaceutical drug producers and distributors in an auction setting. Using detailed data on public procurement of drugs and vertical integrations in Russia, I identify the causal effect of vertical integration on procurement prices. For drugs with few producers, vertical integrations increase prices by 12%, while they decrease prices by 1.7% for drugs with many producers. I propose a model where distributors participating in an auction negotiate with producers. In the equilibrium, foreclosure explains the former empirical result, and the integration synergy drives the latter. I use the model for the structural estimation of producer and distributor cost distributions. Simulations of vertical mergers for drugs with two producers show that mergers with synergies below 4% of the total cost harm buyers, while the observed mergers have estimated synergies of 0.5%–1.5%. I show that for vertical merges with low synergies, the mandatory sharing of the production technology by the merging producer with a new independent firm is an effective remedy. The paper concludes that vertical mergers in concentrated upstream markets require special attention. Antitrust authority may approve a merger if the synergy is substantial or the exogenous upstream entry can be guaranteed.

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8 Appendix

8.1 Appendix A

Table A1: Corporate events that change vertical integration structure

Distributor	Producer	Share change	Event type	Event date
biocad	farmstandart	20% → 70%	Partial merger	31.12.2015
eskom	medpolimer	100% → 0%	Divestiture	04.03.2016
biotek	biosintez	100% → 0%	Divestiture	20.12.2016
sia	biokom	0% → 100%	Full merger	01.02.2017
sia	sintez	17% → 51%	Partial merger	01.02.2017
eskom	medpolimer	0% → 100%	Full merger	08.02.2017
protek	rafarma	0% → 100%	Full merger	17.04.2017
sia	sintez	100% → 0%	Divestiture	29.11.2018
sia	biokom	100% → 0%	Divestiture	29.11.2018

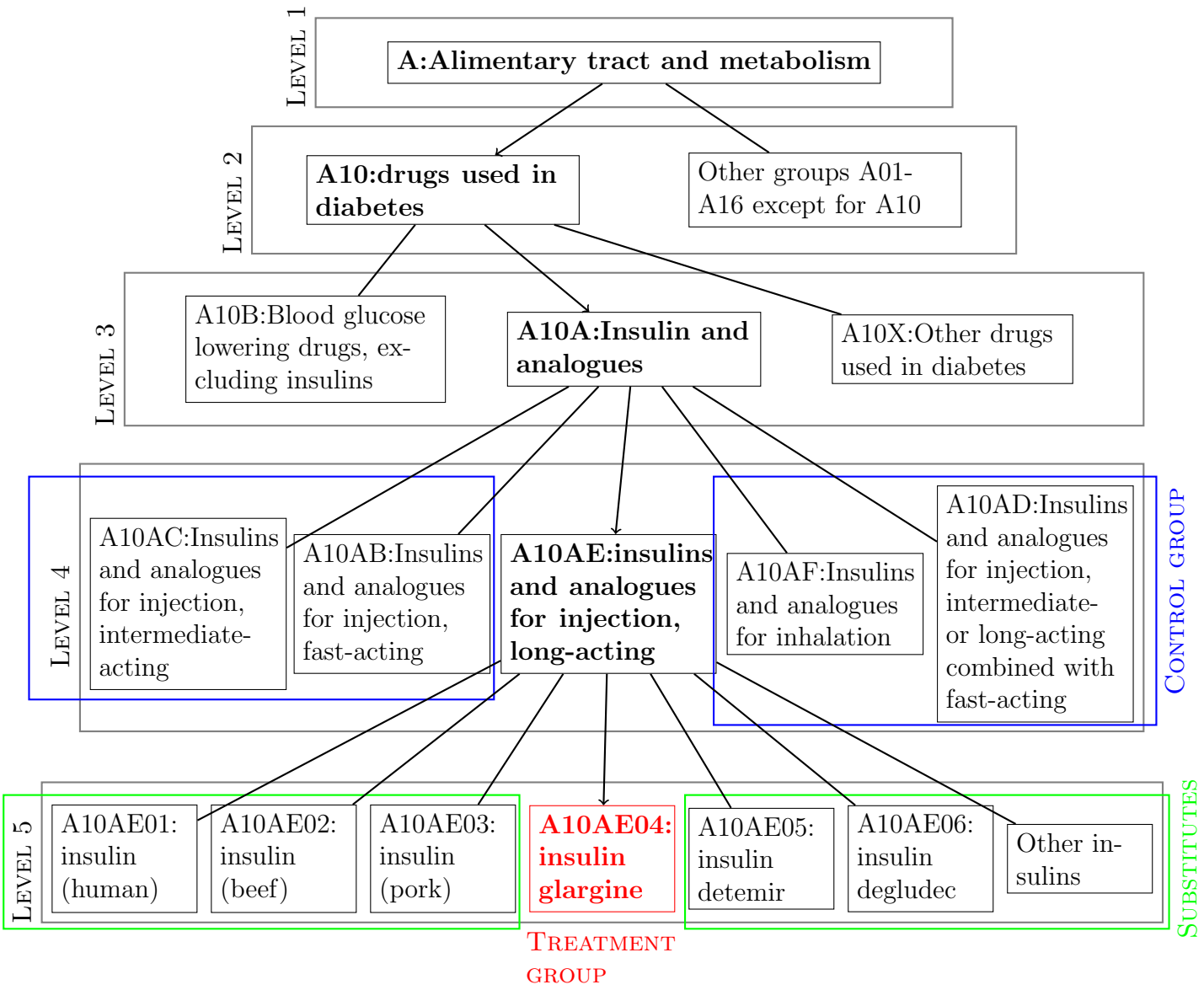
Note. Table shows changes in ownership structure between PD producers and distributors. The full merger implies a change in the ownership share from 0% to at least 50% plus one share. The partial merger implies a change in the ownership share from share higher than 0% to at least 50% plus one share. All VI events, containing SIA as a distributor, were conducted by the financial company Marathon Group, which had a dominant share in SIA as well as acquired partially or fully several producers. In the VI events Farmstandard - Biocad and Eskom-Medpolimer both parts are simultaneously producers and public procurement suppliers of the drugs. Farmstandard supplies drug specifications produced by Biocad quite rarely in my sample (71 drugs), while the opposite is frequent enough (387 drugs). Similarly, Medpolimer supplies drug specifications produced by Eskom not frequently enough in my sample (511 drugs), while the opposite is dominant (3995 drugs). Therefore, I consider only one side of these VI events, where Biocad and Eskom are suppliers. All the results are robust if I consider two sides of these events since new observations add marginally to the estimates.

Table A2: Descriptive statistics of treatment and control groups at the drug level

Supplier	Producer	Obs.	Drug spec.	Mean z-price	Median z-price	St.d. z-price
biocad	Control	59	2	-0.624	-0.944	1.069
biocad	Treatment	378	16	-1.231	-1.266	0.701
biotek	Control	4229	218	-0.069	-0.195	0.924
biotek	Treatment	10526	100	-0.160	-0.296	0.890
eskom	Control	364	22	0.382	0.127	1.177
eskom	Treatment	3871	67	0.369	0.264	1.102
protek	Control	146	43	-0.190	-0.374	1.008
protek	Treatment	248	22	-0.166	-0.342	0.810
sia	Control	1370	159	-0.043	-0.101	0.928
sia	Treatment	3161	117	-0.192	-0.413	0.813
unmerged	Control	525362	843	0.001	-0.079	1.000
unmerged	Treatment	1490452	399	0.001	-0.212	1.000

Note. The table shows the descriptive statistics in the treatment and control groups in auctions, where VI and Non-VI distributors are suppliers, i.e. they are winners of auctions. For calculation of z-prices see the note of Table 1.

Figure A1: ATC classification for insulin glargine



8.2 Appendix B

Table B1: VI effect on share of treated drugs

	Dependent variable: Share of treated drugs			
	Share(total)	Share(1 prod.)	Share(2-4 prod.)	Share($\geq$ 5 prod.)
	(1)	(2)	(3)	(4)
Ln(reserve price)	0.284*	−0.136***	−0.114***	0.534***
	(0.152)	(0.012)	(0.019)	(0.155)
Num. of drug spec.	0.753***	0.012***	0.011***	0.730***
	(0.140)	(0.003)	(0.003)	(0.137)
Duration	0.008***	0.0002***	0.0004**	0.008***
	(0.002)	(0.0001)	(0.0002)	(0.002)
Centr. author.	−3.288**	0.172***	0.694***	−4.154**
	(1.621)	(0.062)	(0.145)	(1.653)
Number of customers	0.789***	−0.0003	−0.008***	0.798***
	(0.057)	(0.001)	(0.003)	(0.057)
If share treat. drugs $\geq 1\% *$ Post VI	22.362***	0.167***	0.540***	21.655***
	(0.664)	(0.018)	(0.039)	(0.638)
If share treat. drugs $\geq 1\% *$ Post VI $*$ VI distr. part.	−3.562***	−0.079*	0.079	−3.562***
	(0.841)	(0.048)	(0.147)	(0.841)
Procurer FE	8055	8055	8055	8055
Year-quarter FE	YES	YES	YES	YES
Observations	814,684	814,684	814,684	814,684
R^2	0.267	0.019	0.015	0.264

*p<0.1; **p<0.05; ***p<0.01

Note. Column 1 has total share of treated drugs in the bundle as dependent variable. Dependent variables in Columns 2, 3, 4 are share of treated drugs in the bundle with 1, 2–4, $\geq$ 5 producers, respectively. Coefficient of the variable *"If share treat. drugs $\geq 1\% *$ Post VI $*$ VI distr. part."* shows how the share of treated drugs change after the VI in auctions, where VI distributors participate compared to auctions, where VI distributors do not participate. Errors are clustered at the procurer level. Variable *VI dist. part.* means that VI distributor is one of participant. Observations are at the bundle level. Sample includes all auctions.

Table B2: Effect of VI on prices if VI distributors participate

	Dependent variable: Log of price-per-unit of drug			
	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)
Quantity: 20-40%	−0.022***	−0.022***	−0.015**	−0.015**
	(0.007)	(0.007)	(0.006)	(0.006)
Quantity: 40-60%	−0.054***	−0.054***	−0.034***	−0.034***
	(0.008)	(0.008)	(0.008)	(0.008)
Quantity: 60-80%	−0.090***	−0.090***	−0.053***	−0.053***
	(0.008)	(0.008)	(0.008)	(0.008)
Quantity: more 80%	−0.137***	−0.137***	−0.070***	−0.070***
	(0.008)	(0.008)	(0.010)	(0.010)
Number of drug spec.	0.002***	0.002***	−0.001	−0.001
	(0.0004)	(0.0004)	(0.001)	(0.001)
Duration	0.00001	0.00001	0.00005**	0.00005**
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Centr. procurement	−0.038***	−0.038***	−0.004	−0.004
	(0.007)	(0.007)	(0.009)	(0.009)
ATT	−0.017***		−0.015**	
	(0.006)		(0.006)	
ATT (1 producer)		0.114*		0.056
		(0.065)		(0.075)
ATT (2-4 producers)		0.135**		0.128**
		(0.055)		(0.055)
ATT (at least 5 producers)		−0.018***		−0.016***
		(0.006)		(0.006)
Num. of applicants			−0.092***	−0.092***
			(0.009)	(0.009)
Drug spec. FE	850	850	850	850
Region FE	YES	YES	YES	YES
Distributor FE	YES	YES	YES	YES
Year-quarter FE	YES	YES	YES	YES
ATC3-year FE	YES	YES	YES	YES
Observations	123,074	123,074	122,971	122,971
R^2	0.955	0.955	0.953	0.953

*p<0.1; **p<0.05; ***p<0.01

Note: See description of Table 3.

Table B3: Effect of VI on prices if VI distributors do not participate

	Dependent variable: Log of price per unit of drug			
	VI dist. part.	VI dist. part.	No VI dist.	No VI dist.
	(1)	(2)	(3)	(4)
Quantity: 20-40%	−0.051***	−0.051***	−0.049***	−0.049***
	(0.009)	(0.009)	(0.009)	(0.009)
Quantity: 40-60%	−0.087***	−0.087***	−0.081***	−0.081***
	(0.013)	(0.013)	(0.015)	(0.015)
Quantity: 60-80%	−0.134***	−0.134***	−0.122***	−0.121***
	(0.018)	(0.018)	(0.022)	(0.022)
Quantity: more 80%	−0.199***	−0.199***	−0.176***	−0.176***
	(0.022)	(0.022)	(0.029)	(0.029)
Number of drug spec.	0.001	0.001	0.0001	0.0001
	(0.001)	(0.001)	(0.0004)	(0.0004)
Duration	0.0001***	0.0001***	0.0001***	0.0001***
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Centr. procurement	−0.041***	−0.041***	−0.024***	−0.024***
	(0.007)	(0.007)	(0.008)	(0.008)
ATT	−0.033**		−0.032*	
	(0.017)		(0.017)	
ATT (1 producer)		−0.065		−0.070
		(0.047)		(0.048)
ATT (2-4 producers)		0.028		0.025
		(0.026)		(0.025)
ATT (at least 5 producers)		−0.034**		−0.033*
		(0.017)		(0.017)
Num. of applicants			−0.043**	−0.043**
			(0.020)	(0.020)
Drug spec. FE	1242	1242	1242	1242
Region FE	YES	YES	YES	YES
Distributor FE	YES	YES	YES	YES
Year-quarter FE	YES	YES	YES	YES
ATC3-year FE	YES	YES	YES	YES
Observations	1,909,394	1,909,394	1,905,849	1,905,849
R^2	0.962	0.962	0.963	0.963

*p<0.1; **p<0.05; ***p<0.01

Note: See description of Table 4.

Figure B1: Event-study for price-per-unit. VI distributors participate

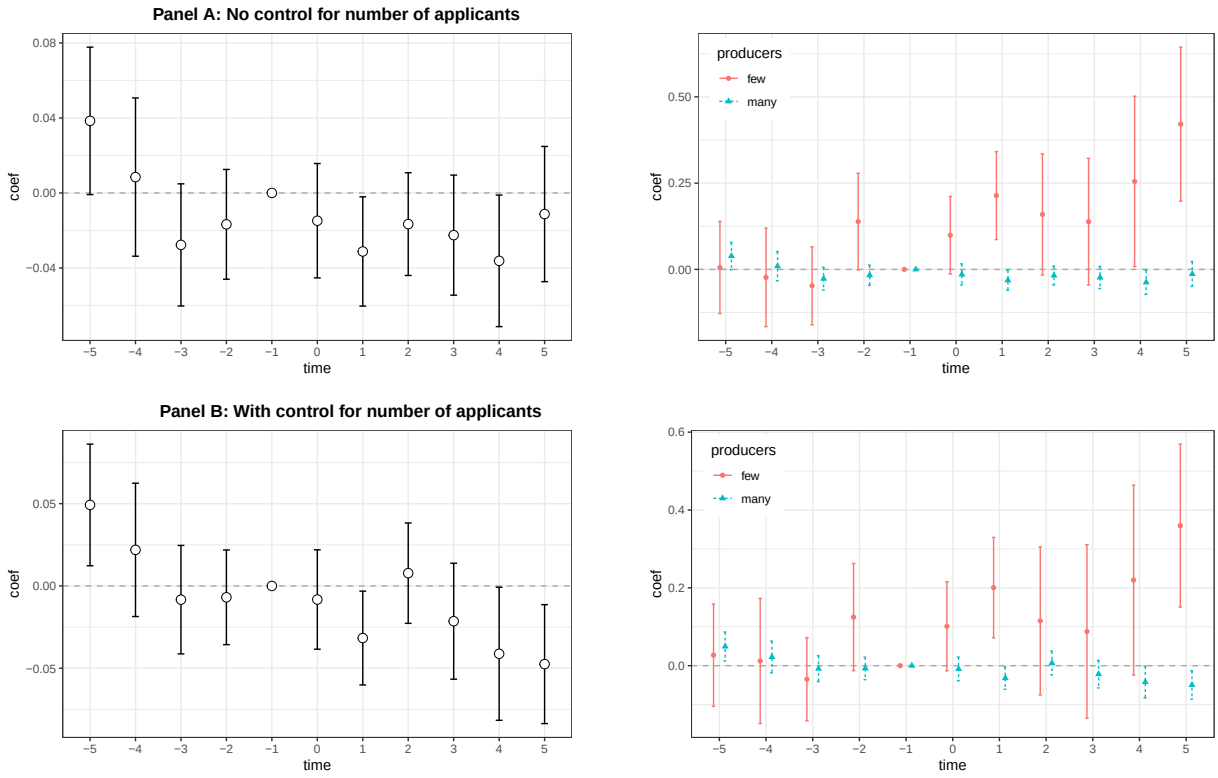
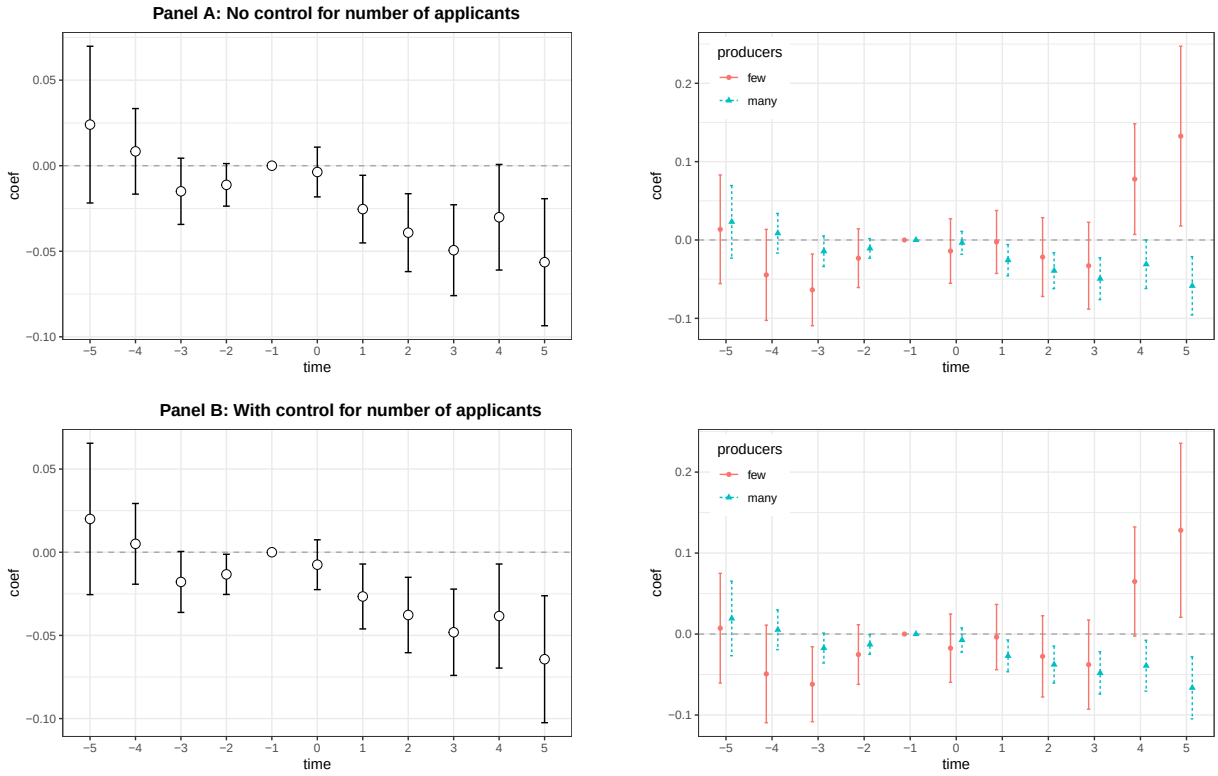


Figure B2: Event-study for price-per-unit. VI distributors do not participate



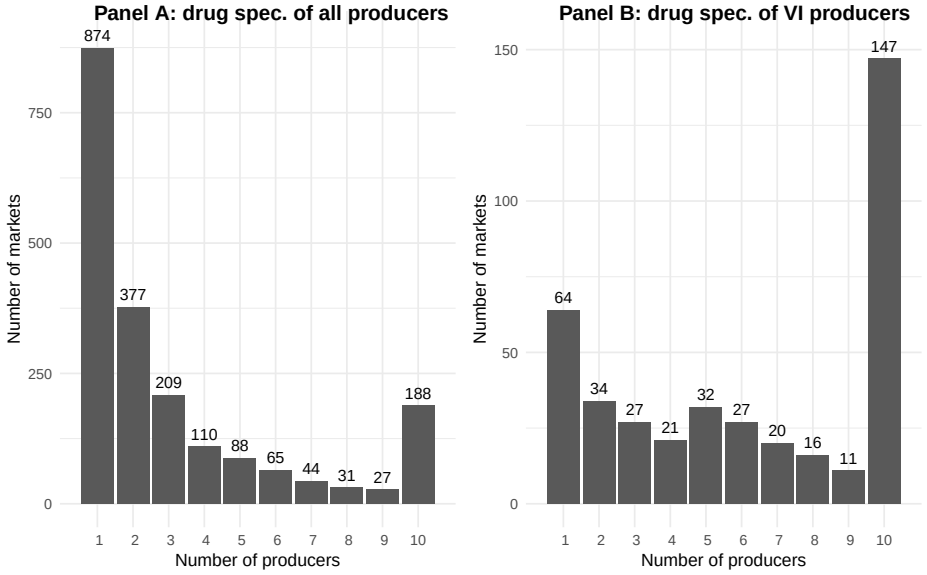
8.3 Appendix C

Table C1: Effect of VI on prices - stack regression approach

	Log of price-per-unit			
	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)
ATT	0.004		-0.026^{**}	
	(0.010)		(0.012)	
ATT (1 producer)		0.110		0.087
		(0.163)		(0.152)
ATT (2-4 producers)		0.112^{**}		0.079^{*}
		(0.048)		(0.048)
ATT ($\geq$ 5 producers)		0.004		-0.026^{**}
		(0.010)		(0.012)
Num. of applicants			-0.083^{***}	-0.083^{***}
			(0.007)	(0.007)
F stat. (1st stage)			109.03	108.99
Drug spec. FE	592	592	591	591
Region FE	YES	YES	YES	YES
Stack-year-quarter FE	YES	YES	YES	YES
R^2	0.954	0.954	0.954	0.954
Note:				*p<0.1; **p<0.05; ***p<0.01

Note. Table shows the result of stack regression approach for the sameple of auctions, where VI distributors participate. For the rest of description see Note of Table 3.

Figure C1: Distribution of the number of producers by geographical markets



Note. For all drugs in the sample Panel A shows the distribution of the number of producers by markets. Market is defined as combination of drug specification and Western/Eastern position of a buyer. Panel B shows the same distribution, but for markets, where VI producers act. Markets with more than 10 producers are binned at the bin of 10 producers.

Table C2: Effect of VI on prices - geographical markets

	Dependent variable: Log of price-per-unit of drug			
	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)
ATT	-0.017^{***}		-0.015^{**}	
	(0.006)		(0.006)	
ATT (1 producer)		0.124^{**}		0.050
		(0.062)		(0.072)
ATT (2-4 producers)		0.099^{**}		0.091^{**}
		(0.041)		(0.042)
ATT (at least 5 producers)		-0.018^{***}		-0.016^{***}
		(0.006)		(0.006)
Num. of applicants			-0.092^{***}	-0.092^{***}
			(0.009)	(0.009)
# drug spec. FE	850	850	850	850
Observations	123,074	123,074	122,971	122,971
R^2	0.955	0.955	0.953	0.953

*p<0.1; **p<0.05; ***p<0.01

Note. Market is defined as combination of drug specification and Western-Eastern location of public buyers. The number of producers for each market is calculated as the number of distinct producers manufacturing brands ever supplied in this market in my data. For the rest of description see Note of Table 3.

Table C3: Effect of VI on prices - alternative instruments

	Panel A: Log of price-per-unit of drug					
	Original instruments		Alternative instrument		Altern. and origin. instruments	
	(1)	(2)	(3)	(4)	(5)	(6)
ATT	−0.015**		−0.016***		−0.016***	
	(0.006)		(0.005)		(0.006)	
ATT (1 producer)		0.056		0.084		0.078
		(0.075)		(0.068)		(0.069)
ATT (2-4 producers)		0.128**		0.133**		0.132**
		(0.055)		(0.054)		(0.054)
ATT (at least 5 producers)		−0.016***		−0.017***		−0.017***
		(0.006)		(0.005)		(0.006)
Num. of applicants	−0.092***	−0.092***	−0.048***	−0.048***	−0.056***	−0.056***
	(0.009)	(0.009)	(0.004)	(0.004)	(0.003)	(0.003)
Drug spec. FE	850	850	850	850	850	850
Observations	122,971	122,971	122,971	122,971	122,971	122,971
R^2	0.953	0.953	0.956	0.956	0.956	0.956
	Panel B: Number of applicants					
	Original instruments		Alternative instrument		Altern. and origin. instruments	
	(1)	(2)	(3)	(4)	(5)	(6)
Share of treated drugs	0.009***	0.009***			0.008***	0.008***
	(0.001)	(0.001)			(0.0005)	(0.0005)
Share of treated drugs * post VI	−0.003***	−0.003***			−0.002***	−0.002***
	(0.001)	(0.001)			(0.001)	(0.001)
Max. num. of applicants			0.213***	0.213***	0.210***	0.210***
			(0.006)	(0.006)	(0.007)	(0.007)
F statistics	144.78	144.89	1085.96	1086.46	585.45	585.32
R^2	0.525	0.525	0.548	0.548	0.554	0.554

*p<0.1; **p<0.05; ***p<0.01

Note. Column 1-2 are identical to Columns 3-4 of Table 3. Columns 3-4 use *Maximum number of applicants* within cluster "Active ingredient-region-year" as an instrument. Columns 5-6 use both original instruments and alternative instrument. Panel A shows 2SLS estimates and Panel B shows first stage estimates. For the rest of description see Note of Table 3.

Table C4: Effect of VI on prices - control for potential corruption

	Dependent variable: Log of price-per-unit of drug			
	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)
ATT	-0.025^{***}		-0.013^{**}	
	(0.006)		(0.006)	
ATT (1 producer)		0.103^{*}		0.055
		(0.063)		(0.071)
ATT (2-4 producers)		0.135^{**}		0.139^{**}
		(0.057)		(0.058)
ATT (at least 5 producers)		-0.026^{***}		-0.014^{**}
		(0.006)		(0.006)
Num. of applicants			-0.086^{***}	-0.085^{***}
			(0.012)	(0.012)
# drug spec. FE	850	850	850	850
Buyer-Supplier FE	21853	21853	21842	21842
Observations	123,074	123,074	122,971	122,971
R^2	0.968	0.968	0.968	0.968

*p<0.1; **p<0.05; ***p<0.01

Note. Joined buyer-supplier fixed effects are introduced in Equations (1) and (2). For the rest of description see Note of Table 3.

8.4 Appendix D

Properties of $p_M^*(c)$

The second term in equation (3) is $\mathbf{P}\left(p + \min(d_1, \ldots, d_M) \leq r\right) = 1 - (1 - G(r-p))^M \equiv G_M(r - p)$, where $G_M(x)$ is the distribution of the minimum of delivery costs $\min(d_1, \ldots, d_M)$ among m distributors with density $g_M(x)$. The first-order condition of (3) yields that $p_M^*(c)$ is a solution of the following equation:

$$p - c = \frac{G_M(r-p)}{g_M(r-p)}. \tag{12}$$

The log-concavity of $G(x)$ yields the log-concavity of $G_M(x)$ (Bagnoli and Bergstrom (2005)). This in turn guarantees the second-order condition of (3)is satisfied and $p_M^*(c)$ is non-decreasing in c. Notice that G_{M-1} dominates G_M in terms of the reverse hazard rate, so $p_M^*(c)$ is increasing in M.

Proof of Proposition 1.

For a sequence of variables $\{X_1+\nu, X_2, X_3, \ldots X_m\}$ and ν by $X_k^{(m)}(\nu)$ denote the kth smallest value of the sequence, i.e. $X_1^{(m)}(\nu) = min\{X_1 + \nu, X_2, X_3, \ldots X_m\}$. If $\nu = 0$ denote $X_k^{(m)} \equiv X_k^{(m)}(0)$. It is immediate to see that $X_k^{(m)}(\nu)$ is non-decreasing function of ν. By $X_k^{(m-1)}$ denote the kth smallest value of the sequence $\{X_2, X_3, \ldots X_m\}$ without X_1. The game is solved backward.

First, consider the VS-scenario. At Stage 2 independent distributors participate in the descending auction. Therefore, the weakly dominant strategy of the distributor j is to stay in the auction until the current price reaches the total cost $\widetilde{tc}_j = p_j + d_j$. Delivery cost is exogenous, while input price p_j is a result of the negotiation. Now let us consider Stage 1. Recall, in VS-scenario all the distributors are symmetric from the perspective of the producer, so she sets the identical price $p \in [c_1, \overline{p}]$ to all the distributors, i.e. $p_j = p$. Since the producer is profit maximizer, she solves the maximization problem (3) subject to $p \leq \overline{p}$. By Assumption 1 the solution is $p = \overline{p}$. Therefore, the total cost of distributor j in VS scenario is $\widetilde{tc}_j = \overline{p} + d_j$ and the buyer payment is the second smallest among the total costs $p^{vs} = \widetilde{tc}_2^{(m)}$, conditional on trade and the downstream competition.

The the expected buyer payment (conditional that trade occurs)[45] is

$$\mathbf{E}p^{vs} = \mathbf{E}\left(\min(\overline{p} + d_2^{(m)}, r)\Big| \overline{p} + d_1^{(m)} \leq r\right). \tag{13}$$

Now, consider the VI scenario. By assumption P_1 commits to work with all m distributors. D_1 receives the drug at a cost $c_1 - \delta$, so his total cost is $tc_1 = c_1 - \delta + d_1$. The input price of rival distributors includes mark-up $\mu = p - c_1$, which is identical for all distributors due to the symmetry, i.e. their total cost is $tc_j = c_1 + \mu + d_j$ $(j = \overline{2, m})$. Let me consider Stage 2. Due to the vertical integration with P_1, D_1 knows what mark-up μ the producer sets to the other distributors. Because of descending auction at the downstream level, for each current bid level b of the bidding process, D_1 can infer that payoff $b - c_1 - \mu$ goes to the distributor who made this bid, and the rest $c_1 + \mu$ is passing to the producer. If at some moment of bidding process the bid level reaches $b = c_1 + \mu + d_1 - \delta$, D_1 has no more incentives to stay in the auction (if he is still in). Indeed, if D_1 continues to stay in the auction the total profit of D_1 and P_1 becomes less than μ, but if he leaves the auction, the profit of P_1 is guaranteed to be μ. Therefore, the weakly dominant strategy of D_1 is to stay until $c_1 + \mu + d_1 - \delta$ rather than until his total cost tc_1, i.e. D_1 behaves as if he is vertically separated but having the discount parameter δ. Anticipating such behavior of D_1, at Stage 1 the VI-producer P_1 solves the following maximization problem

$$\max_{p \leq \overline{p}} (p - c_1)\mathbf{P}(min(tc_1, \ldots, tc_m) \leq r). \tag{14}$$

Notice that that for any input price $p > 0$ and $\delta \geq 0$ random variable $p + \min(d_1, \ldots, d_m)$ dominates $min\left(c_1 - \delta + d_1, p + \min(d_2, \ldots, d_m)\right)$ in terms of reverse hazard rate. Therefore, the unrestricted solution $p_m^{vi}(c_1)$ of (14) is not smaller than the unrestricted solution of (3), i.e. $p_m^{vi}(c_1) \geq p_m^*(c_1)$, so by Assumption 1, restricted solution of (14) is $p = \overline{p}$. Note that probability that trade occurs in (14) of VI-scenario is higher compared to the one in (3) of VS-scenario for any p, because due to efficiency gain D_1 is more likely to enter the auction. This means that without the upper bound $\overline{p}$, VI producer would like to set higher price than $p_m^*(c_1)$. Therefore, conditional on trade and downstream competition, the buyer payment is $tc_2^{(m)} = \widetilde{tc}_2^{(m)}(-\delta)$ and conditional expected buyer

[45] One call also consider the unconditional expected buyer payment, but in this case the assumption about continuation of the game is required if trade does not occur. One should assume that the buyer has an outside option where she can buy at the reserve price, or she runs another auction with a higher reserve price. Moreover, my data includes only auctions with least one bidder, i.e. auctions where contracts are signed.

payment is

$$\mathbf{E}p^{vi} = \mathbf{E}\left(\min(\widetilde{tc}_2^{(m)}(-\delta), r)\middle| min(tc_1, \ldots, tc_m) \leq r\right). \tag{15}$$

Notice $\widetilde{tc}_2^{(m)}(-\delta) \leq \widetilde{tc}_2^{(m)}$ point-wise. This inequality is strict with positive probability when $\delta > 0$, e.g. when D_1 has the second smallest total cost in VS-scenario. Therefore, for $\delta = 0$ we have $\mathbf{E}p^{vs} = \mathbf{E}p^{vi}$ and for $\delta > 0$ we have $\mathbf{E}p^{vs} > \mathbf{E}p^{vi}$. ■

Multiple producer case: definition of equilibrium

First, consider the VS-scenario. The game is solved backward. At Stage 2, the weakly dominant strategy of distributor j is to stay in the auction until the current price reaches the total cost $\widetilde{tc}_j = p_j + d_j$. When $n > 1$, at Stage 1 each distributor runs an inner descending open auction among all producers and chooses the minimal price. Since all the inner auctions are run simultaneously for the same realization of production costs $(c_i)_{i=1}^n$, the producer with the minimal cost wins all the inner auctions[46] and the input price of all distributors is $p_j = c_2^{(n)}$.[47] Therefore, the total cost of distributor j is $\widetilde{tc}_j = c_2^{(n)} + d_j$ and the expected buyer payment is

$$\mathbf{E}p^{vs} = \mathbf{E}\left(c_2^{(n)} + d_2^{(m)}\right). \tag{16}$$

Now, consider the VI-scenario and assume that P_1 commits to work with all the distributors. Let $c_1 + \mu$ be the ultimate offer of P_1 at Stage 1 in negotiations with rival distributors, which is the same for all rivals distributors due to symmetry. Strategy $\mu \in [0, \overline{p} - c_1]$ is what P_1 chooses to maximize expected profit of the integrated firm $P_1\&D_1$. Choice of μ characterizes the RRC effect.

Consider the case, when at Stage 2 the VI producer P_1 is the input supplier of all distributors. In this case, the total costs of D_1 is $tc_1 = c_1 - \delta + d_1$. Moreover, P_1 was able to overbid all other independent producers at Stage 1, i.e. $c_1 + \mu \leq c_1^{(n-1)}$. Therefore, the input prices of rival distributors is $p_j = c_1^{(n-1)}$ and their total costs is $tc_j = c_1^{(n-1)} + d_j$ $(j \in \{2, \ldots, m\})$. Since P_1 supplies to all distributors, at Stage 2, similarly to the case of $n = 1$, D_1 stays in the auction until

[46] In non-cooperative equilibrium, producers do not split between distributors, as the minimal cost producer has always incentives to marginally undercut other producers in all the inner auctions and to become the supplier of all distributors.

[47] Note that $c_2^{(n)}$ is not parametrized by j, i.e. each distributor has the same input price and potentially the same input supplier. The assumption that negotiation process of each distributor is run for the same realization of production costs $(c_i)_{i=1}^n$ does not affect the ex-ante expected buyer payment, but simplifies derivations.

price reaches $c_1^{(n-1)} - \delta + d_1$ rather than $c_1 - \delta + d_1$. Indeed, if D_1 observes that $d_1 - \delta > d_1^{(m-1)}$, he has no incentives to win the auction, because if he looses then the profit of P_1 is $c_1^{(n-1)} - c_1$, but if he wins then the total profit of $P_1\&D_1$ is lower. Therefore, the total profit of $P_1\&D_1$ is $c_1^{(n-1)} - c_1 + d_1^{(m-1)} - d_1 + \delta$ if $d_1 - \delta \leq d_1^{(m-1)}$, and $c_1^{(n-1)} - c_1$ otherwise.

Consider the case, when at Stage 2 VI producer P_1 is not the input supplier of all distributors, i.e. P_1 is an input supplier either for D_1 or for nobody. In this case, at Stage 2 all the distributors stay in the procurement auction until their total costs $tc_j = p_j + d_j$. If $tc_1 \leq tc_1^{(m-1)}$ then D_1 wins and $P_1\&D_1$ aggregate profit is $tc_1^{(m-1)} - tc_1$, otherwise D_1 looses and $P_1\&D_1$ earn zero. At Stage 1 the negotiation process defines the input prices of distributors. The equilibrium input price of D_1 is $p_1 = min\left(c_2^{(n-1)}, c_1 - \delta\right)$. Rival producer with the lowest cost wins the inner auctions of all rival distributors at the price $c_2^{(n)}(\mu)$. Note that $c_2^{(n)}(\mu)$ is non-decreasing in μ. The lowest cost rival producer anticipates that P_1 can strategically increase μ in order to raise costs of rival distributors, so she may want to give additional rebate ρ to the price $c_2^{(n)}(\mu)$ for rival distributors in response to this strategy.[48] Therefore the total cost of distributors are:

$$\begin{aligned} tc_1 &= min\left(c_2^{(n-1)}, c_1 - \delta\right) + d_1. \\ tc_j &= c_2^{(n)}(\mu) - \rho + d_j \quad (j \in \{2, \ldots, m\}) \end{aligned} \tag{17}$$

Let me introduce the following events:

(i) $A = \left\{c_1 + \mu \leq c_1^{(n-1)}\right\}$, when P_1 is the input supplier to all distributors;

(ii) $B = \left\{c_1^{(n-1)} < c_1 - \delta\right\}$, when P_1 is not an input supplier to any distributor;

(iii) $C = \left\{c_2^{(n-1)} < c_1 - \delta\right\}$, when P_1 is not an input supplier to any distributor and D_1 input price is lower than $c_1 - \delta$;

(iv) $D = \left\{d_1 - \delta < d_1^{(m-1)}\right\}$, when delivery cost of D_1 (including the efficiency gain) is the lowest one;

(v) $E = \left\{tc_1 < tc_1^{(m-1)}\right\}$, when the total cost of D_1 is the lowest and tc_j are defined in (17).

Notice that $C \subset B \subset \overline{A}$, so $\overline{A} \cap \overline{B}$ means that P_1 is the input supplier to D_1 only. The equilibrium strategies of the game are functions $\mu(c_1) : [\underline{c}, \overline{c}] \to [0, \overline{p} - c_1]$ and $\rho(c_1^{(n-1)}, c_2^{(n)}(\mu)) : [\underline{c}, \overline{c}] \times [\underline{c}, \overline{p}] \to$

[48] Note that lowest cost rival producer observes $c_2^{(n)}(\mu)$, but not c_1. Moreover, in many cases she cannot infer c_1 from $c_2^{(n)}(\mu)$ as $c_2^{(n)}(\mu)$ is not necessary strictly monotone in c_1.

$\mathbb{R}^+$ that solve the following system of maximization problems:

$$\begin{aligned} \underset{\mu}{argmax}\ & \mathbf{E}\left(c_1^{(n-1)} - c_1 + d_1^{(m-1)} - d_1 + \delta \middle| c_1, \rho, A \cap D\right) \mathbf{P}(A \cap D | c_1, \rho) + \\ & \mathbf{E}\left(c_1^{(n-1)} - c_1 \middle| c_1, \rho, A \cap \bar{D}\right) \mathbf{P}(A \cap \bar{D} | c_1, \rho) + \\ & \mathbf{E}\left(tc_1^{(m-1)} - tc_1 \middle| c_1, \rho, \bar{A} \cap E\right) \mathbf{P}(\bar{A} \cap E | c_1, \rho); \end{aligned} \tag{18}$$

$$\underset{\rho}{argmax}\ \left(c_2^{(n)}(\mu) - \rho - c_1^{(n-1)}\right) \mathbf{P}\left(\bar{E} \middle| c_2^{(n)}(\mu), c_1^{(n-1)}, \mu, \bar{A} \cap \bar{B}\right). \tag{19}$$

The expected buyer payment is

$$\begin{aligned} \mathbf{E}p^{vi} = & \mathbf{E}\left(c_1^{(n-1)} + d_1^{(m-1)} \middle| A \cap D\right) \mathbf{P}(A \cap D) + \\ & \mathbf{E}\left(c_1^{(n-1)} + \min\left\{d_1 - \delta, d_2^{(m-1)}\right\} \middle| A \cap \bar{D}\right) \mathbf{P}(A \cap \bar{D}) + \mathbf{E}\left(tc_2^{(m)} \middle| \bar{A}\right) \mathbf{P}(\bar{A}). \end{aligned} \tag{20}$$

Proof of Proposition 2.

Preliminary setting.

To prove Proposition 2 I consider Non-VI and VI scenario in parallel, i.e. I will assume that realizations of random variables c_i ($i = \overline{1,n}$) and d_j ($j = \overline{1,m}$) are the same for both cases. From ex-ante perspective (i.e. expectation of buyer's payment) this makes no difference as if I consider cases before and after the VI separately. I start with an auxiliary lemma.

Lemma 1. $\lim\limits_{n\to\infty} \mathbf{E}c_2^{(n)}(\mu) - \mathbf{E}c_2^{(n)}(0) = 0.$

Proof of Lemma 1. First let me find the pdf of $c_2^{(n)}$.

$$\mathbf{P}\left(c_2^{(n)} > x\right) = \mathbf{P}\left(c_1^{(n)} > x\right) + \mathbf{P}\left(c_2^{(n)} > x, c_1^{(n)} < x\right) = (1 - F(x))^n + n\,(1 - F(x))^{n-1}\,F(x).$$

So the pdf of $c_2^{(n)}$ is

$$f_2(x) = -\mathbf{P}\left(c_2^{(n)} > x\right)' = n(n-1)F(x)\,(1 - F(x))^{n-2}\,f(x).$$

Denote by $c_2^{(n-1)}$ the second smallest element of the sequence $(c_2, \ldots, c_n)$ without element c_1.

Recall that by assumption $f(x)$ has finite support $[\underline{c}, \overline{c}]$. Let me calculate

$$\mathbf{E}c_2^{(n-1)} - \mathbf{E}c_2^{(n)} = \int_a^b x(n-1)(n-2)F(x)\left(1-F(x)\right)^{n-3} f(x)dx -$$

$$\int_a^b xn(n-1)F(x)\left(1-F(x)\right)^{n-2} f(x)dx = \int_a^b x(n-1)f(x)F(x)\left(1-F(x)\right)^{n-3}\left(nF(x)-2\right)dx \leq$$

$$\int_a^b x(n-1)f(x)F(x)\left(1-F(x)\right)^{n-3}(n-2)dx \xrightarrow[n\to\infty]{} 0$$

as $(n-1)(n-2)\left(1-F(x)\right)^{n-3} \xrightarrow[n\to\infty]{} 0$ for all $x \in (\underline{c}, \overline{c}]$. Note also that $c_2^{(n-1)} - c_2^{(n)} \geq 0$ as $c_2^{(n)}$ is the second smallest among n realizations, while $c_2^{(n-1)}$ is the second smallest among the same realizations except for the first one. Therefore, $\lim\limits_{n\to\infty} \mathbf{E}c_2^{(n-1)} - \mathbf{E}c_2^{(n)} = 0$. As $c_2^{(n-1)} \geq c_2^{(n)}(\mu) \geq c_2^{(n)}(0)$, we have that $\lim\limits_{n\to\infty} \mathbf{E}c_2^{(n)}(\mu) - \mathbf{E}c_2^{(n)}(0) = 0$. ■

Proof of Proposition 2.

Recall that pre-merger the total cost of jth ($j = \overline{1,m}$) distributor is $\widetilde{tc}_j = c_2^{(n)}(0) + d_j$ and the buyer payment is $\widetilde{tc}_2^{(m)} = c_2^{(n)}(0) + d_2^{(m)}$. The post-merger total costs of D_1 is $tc_1 = \min\left(c_2^{(n)}(0), c_1 - \delta\right) + d_1$, total costs of jth ($j = \overline{2,m}$) distributor is $tc_j = c_2^{(n)}(\mu) - \rho + d_j$. Note that the event when P_1 is the input supplier for all distributors has zero probability in limit. Indeed, $\mathbf{P}\left(c_1 + \mu \leq c_1^{(n-1)}\right) \leq \frac{1}{n}$ (as c_i are iid), so $\mathbf{P}\left(c_1 + \mu \leq c_1^{(n-1)}\right) \xrightarrow[n\to\infty]{} 0$. Henceforth, I consider the event when P_1 is not the input supplier for all distributors. Under this event the payment of buyer is $tc_2^{(m)}$. Note that $tc_2^{(m)}$ is non-increasing in ρ, so it is enough to prove Proposition 2 for $\rho = 0$. For the rest of the proof consider $\rho = 0$. Let me decompose the expected post-merger payment of the buyer by several events and compare post- and pre- merger conditional expected payments.

$$\begin{aligned}\mathbf{E}tc_2^{(m)} =& \mathbf{E}\left(tc_2^{(m)} \middle| tc_1 = tc_1^{(m)}\right)\mathbf{P}\left(tc_1 = tc_1^{(m)}\right) + \\ & \mathbf{E}\left(tc_2^{(m)} \middle| tc_1 = tc_2^{(m)}\right)\mathbf{P}\left(tc_1 = tc_2^{(m)}\right) + \\ & \mathbf{E}\left(tc_2^{(m)} \middle| tc_1 > tc_2^{(m)}\right)\mathbf{P}\left(tc_1 > tc_2^{(m)}\right).\end{aligned} \tag{21}$$

The first summand is for the event when D_1 has minimal total cost, the second - D_1 has the second smallest total cost, the third - D_1 has the third minimal total cost or larger. Conditional expectation of the first summand of (21) can be further decomposed into two events - when D_1

wins pre-merger and when D_1 looses pre-merger and wins post-merger.

$$\begin{aligned}\mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_1^{(m)}\right.\right)=\mathbf{E}\left(tc_2^{(m)}\left|d_1=d_1^{(m)}\right.\right)\mathbf{P}\left(d_1=d_1^{(m)}\right)+\\ \mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)\mathbf{P}\left(tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right)\end{aligned}\tag{22}$$

The conditional expectation of the first summand of (22) satisfies

$$\begin{aligned}\mathbf{E}\left(tc_2^{(m)}\left|d_1=d_1^{(m)}\right.\right)=\mathbf{E}\left(c_2^{(n)}(\mu)+d_2^{(m)}\left|d_1=d_1^{(m)}\right.\right)\geq\\ \mathbf{E}\left(c_2^{(n)}(0)+d_2^{(m)}\left|d_1=d_1^{(m)}\right.\right)=\mathbf{E}\left(\widetilde{tc}_2^{(m)}\left|d_1=d_1^{(m)}\right.\right)\end{aligned}\tag{23}$$

This case corresponds to the event when D_1 wins auction pre-merger, and so wins post-merger. However, the post-merger the cost of the second winner is higher as $c_2^{(n)}(\mu)\geq c_2^{(n)}(0)$, so the ex-ante expected payment increases.

The conditional expectation of the second summand of (22) satisfies

$$\begin{aligned}\mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)=&\mathbf{E}\left(c_2^{(n)}(\mu)\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)+\\ &\mathbf{E}\left(d_1^{(m)}\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)\end{aligned}\tag{24}$$

This case corresponds to the event when D_1 wins auction post-merger, bust looses pre-merger. Ex-ante expected buyer payment can either increase because $c_2^{(n)}(\mu)\geq c_2^{(n)}(0)$ and so

$$\mathbf{E}\left(c_2^{(n)}(\mu)\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)\geq\mathbf{E}\left(c_2^{(n)}(0)\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)\tag{25}$$

or decrease because $d_1^{(m)}\leq d_2^{(m)}$ and so

$$\mathbf{E}\left(d_1^{(m)}\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)\leq\mathbf{E}\left(d_2^{(m)}\left|tc_1=tc_1^{(m)},d_1>d_1^{(m)}\right.\right)\tag{26}$$

The exact sign will depend on distributions $F(.)$ and $G(.)$

Conditional expectation of the second summand of (21) can be further decomposed into three events: when D_1 is second best before and after the merger, D_1 becomes the second best after VI

because of efficiency gain, D_1 becomes the second best after VI because of rivals foreclosure.

$$\begin{aligned}\mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_2^{(m)}\right.\right)=\mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_2^{(m)},d_1=d_2^{(m)}\right.\right)\mathbf{P}\left(tc_1=tc_2^{(m)},d_1=d_2^{(m)}\right)+\\ \mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(0)\right.\right)\\ \mathbf{P}\left(tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(0)\right)+\\ \mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_2^{(m)}+c_2^{(n)}(0)<d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(\mu)\right.\right)\\ \mathbf{P}\left(tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_2^{(m)}+c_2^{(n)}(0)<d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(\mu)\right)+\end{aligned} \tag{27}$$

The conditional expectation of the first summand of (27) satisfies

$$\begin{aligned}\mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_2^{(m)},d_1=d_2^{(m)}\right.\right)=\mathbf{E}\left(d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)\left|tc_1=tc_2^{(m)},d_1=d_2^{(m)}\right.\right)\leq\\ \mathbf{E}\left(d_1+c_2^{(n)}(0)\left|tc_1=tc_2^{(m)},d_1=d_2^{(m)}\right.\right)=\mathbf{E}\left(\widetilde{tc}_2^{(m)}\left|tc_1=tc_2^{(m)},d_1=d_2^{(m)}\right.\right)\end{aligned} \tag{28}$$

as $\min\left(c_2^{(n)}(0),c_1-\delta\right)\leq c_2^{(n)}(0)$. This case corresponds to the event when D_1 is the second best pre-merger and post-merger. However, cost of D_1 decreases because of efficiency gain and so the ex-ante expected buyer payment decreases.

The conditional expectation of the second summand of (27) satisfies

$$\begin{aligned}\mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(0)\right.\right)\leq\\ \mathbf{E}\left(d_2^{(m)}+c_2^{(n)}(0)\left|tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(0)\right.\right)\end{aligned} \tag{29}$$

by the way the event is defined. This case corresponds to the event when D_1 becomes more efficient than the pre-merger second-best, so the ex-ante expected buyer payment decreases.

The conditional expectation of the third summand of (27) satisfies

$$\begin{aligned}\mathbf{E}\left(tc_2^{(m)}\left|tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_2^{(m)}+c_2^{(n)}(0)<d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(\mu)\right.\right)\geq\\ \mathbf{E}\left(d_2^{(m)}+c_2^{(n)}(0)\left|tc_1=tc_2^{(m)},d_1>d_2^{(m)},d_2^{(m)}+c_2^{(n)}(0)<d_1+\min\left(c_2^{(n)}(0),c_1-\delta\right)<d_2^{(m)}+c_2^{(n)}(\mu)\right.\right)\end{aligned} \tag{30}$$

by the way the event is defined. This case corresponds to the event when D_1 becomes the second-best post-merger because input cost of the pre-merger second-best increases, so the ex-ante ex-

pected buyer payment increases.

Conditional expectation of the third summand of (21) satisfies

$$\mathbf{E}\left(tc_2^{(m)}\,\middle|\,tc_1 > tc_2^{(m)}\right) = \mathbf{E}\left(c_2^{(n)}(\mu) + d_2^{(m)}\,\middle|\,tc_1 > tc_2^{(m)}\right) \geq \mathbf{E}\left(c_2^{(n)}(0) + d_2^{(m)}\,\middle|\,tc_1 > tc_2^{(m)}\right), \quad (31)$$

as $c_2^{(n)}(\mu) \geq c_2^{(n)}(0)$. This case corresponds to the event when post-merger D_1 has total cost higher than second-best. In this case the RRC effect increases the ex-ante expected buyer payment.

Let us now look at all the events, when post-merger ex-ante expected buyer payment is higher than the pre-merger one. They are (23), (25), (30), (31). In all these cases, the difference between post-merger and pre-merger ex-ante expected buyer payment does not exceed expectation of $c_2^{(n)}(\mu) - c_2^{(n)}(0)$ (conditional on the corresponding event), which by Lemma 1 tends to zero as $n \to \infty$.

Events, where post-merger ex-ante expected buyer payment is lower than the pre-merger one, are (26), (28), (29). In all these events difference between post-merger and pre-merger ex-ante expected buyer payment does not tends to zero $n \to \infty$ and for $\delta > 0$ the events in (28), (29) have positive probability in limit. ■

8.5 Appendix E

Incorporating of unobserved heterogeneity

To incorporate the unobserved heterogeneity per se, I need to impose more structure. If one admits the presence of the unobserved heterogeneity, then the total cost structure has the form

$$tc_{j,a} = \underbrace{c_{2,a}^{(N)}}_{common\,term} + \underbrace{d_{j,a}}_{private\,value} + \underbrace{\beta \mathbf{X_a}}_{observed\,heterogen.} + \underbrace{u_a}_{unobserved\,heterogen.} \tag{32}$$

This form is an extension of 6 incorporating the unobserved heterogeneity term. u_a. Obviously, two bids of an auction cannot identify the distribution of u_a as they are used to identify the distribution of $c_{2,a}^{(N)}$. Additional structure on the reserved price enables to identify the distribution of u_a. Namely, I need to assume the reserve price to be of the following form

$$r_a = \tilde{r_a} + \beta \mathbf{X_a} + u_a \tag{33}$$

On top of this, I need the following additional assumptions on top of Assumptions 2 – 5:

Assumption 6. ***(Independence of unobserved heterogeneity.)*** *Unobserved heterogeneity u_a is independent of producer costs $(c_{i,a})_{i=1}^N$, distributor costs $(d_{j,a})_{j=1}^M$ and of observed heterogeneity $\mathbf{X_a}$.*

Assumption 7. ***(Normalization.)*** *(i) Unobserved heterogeneity is normalized to satisfy $\mathbf{E}(u_a) = 0$; (ii) Characteristic function of u_a has isolated zeros.*

The identification of the unobserved heterogeneity follows the logic of input price identification.

One-to-one correspondence between multiplicative and additive forms of total cost structure

This section shows that there is one-to-one correspondence between multiplicative and additive forms of total cost. Assume the total cost has the following multiplicative form:

$$TC_{j,a} = \underbrace{C_{2,a}^{(N)}}_{common\,term} \cdot \underbrace{D_{j,a}}_{private\,value} \cdot \underbrace{e^{\beta \mathbf{X_a}}}_{observed\,heterogen.} \tag{34}$$

So the winning bid and other order statistics of bids satisfy

$$\begin{aligned} \text{winning bid: } b_{1,a}^{(m)} &= TC_{2,a}^{(M)} \\ \text{other bids: } b_{k,a}^{(m)} &= TC_{k+1,a}^{(M)} \end{aligned} \tag{35}$$

If we take the logarithm of the bids and and all components of the total cost (34), we are back to the additive form, represented in (6):

$$tc_{j,a} = ln(TC_{j,a}),\ c_{2,a}^{(N)} = ln\left(C_{2,a}^{(N)}\right),\ d_{j,a} = ln\left(D_{j,a}\right) \tag{36}$$

$$tc_{j,a} = \underbrace{c_{2,a}^{(N)}}_{common\,term} + \underbrace{d_{j,a}}_{private\,value} + \underbrace{\beta \mathbf{X_a}}_{observed\,heterogen.} \tag{37}$$

Proposition 3: identification of costs distributions

Without loss of generality we can assume absence of the observed heterogeneity as it can be easily identified and subtracted via the regression of the observed bids on the observed characteristics. Let me start from the result, showing how the order statistics of total costs and knowledge of input price identify the distribution of the distribution cost. Consider the conditional probability

$$\mathbf{P}\left(tc_2^{(m)} = x | tc_3^{(m)} = y, c_2^{(N)} = z\right) = \mathbf{P}\left(d_2^{(m)} = x - z | d_3^{(m)} = y - z\right) = \tag{38}$$

$$\mathbf{P}\left(d_2^{(2)} = x - z | d_2^{(2)} \leq y - z\right) = f_{d_2^{(2)}}(x - z | y - z) \tag{39}$$

Now consider the case when the third order statistics of total costs hits the upper bound. Then $\forall x \in [\underline{c} + \underline{d}, \overline{c} + \overline{d}]$ from (38) we have

$$\mathbf{P}\left(tc_2^{(m)} = x | tc_3^{(m)} = \overline{c} + \overline{d}\right) = \mathbf{P}\left(tc_2^{(m)} = x | c_2^{(N)} = \overline{c}, d_3^{(m)} = \overline{d}\right) = f_{d_2^{(2)}}(x - \overline{c})$$

Since we observe the left-hand side in the data, the right hand side identifies the distribution of $d_2^{(2)} + \overline{c}$. However, the upper bound $\overline{c}$ can be unobserved. I identify it from Assumption 4. Namely,

$$\mathbf{E}(d_2^{(2)} + \overline{c}) = \mathbf{E}(d_2^{(2)} + c_2^{(N)}) - \mathbf{E}(c_2^{(N)}) + \overline{c} = \mathbf{E}(tc_2^{(2)}) + \overline{c}. \tag{40}$$

Here I used that $\mathbf{E}(c_2^{(N)}) = 0$. In (40) left-hand side is already identified and term $\mathbf{E}(tc_2^{(2)})$

is observed in the data, so $\overline{c}$ is identified. Therefore, we can identify the distribution of order statistics of d_j and the distribution of d_j is identified from (9).

Now we can identify the distribution of c_i. We observe in the data $tc_2^{(m)} = d_2^{(m)} + c_2^{(N)}$. We already identified the distribution of $d_2^{(m)}$ and the distribution of $c_2^{(N)}$ can be identified from the ratio of characteristic functions under independence Assumption 3:

$$\varphi_{c_2^{(N)}}(t) = \frac{\varphi_{tc_2^{(m)}}(t)}{\varphi_{d_2^{(m)}}(t)}.$$

The distribution of c_i is identified from the distribution of $c_2^{(N)}$ by inversion (9).

Elements of the liklihood function

The likelihood function (11) includes the following elements:

$$p_0 = \mathbf{P}(m=0) = \mathbf{P}(tc_j > r \;\forall\; j) = \int_{-\infty}^{\infty} [1 - G(r-z)]^M \, dF_{c_2^{(N)}}(z) \tag{41}$$

$$p_1 = \mathbf{P}(m=1) = \int_{-\infty}^{\infty} MG(r-z) \, [1 - G(r-z)]^{M-1} \, dF_{c_2^{(N)}}(z) \tag{42}$$

$$\begin{aligned} p_2(x) =& \mathbf{P}(tc_2^{(M)} = x, m=2) = \mathbf{P}(tc_1^{(M)} < x,\, tc_2^{(M)} = x,\, tc_3^{(M)} > r) = \\ & \int_{-\infty}^{\infty} MG(x-z)g(x-z) \, [1 - G(r-z)]^{M-2} \, dF_{c_2^{(N)}}(z) \text{ for } x \le r \end{aligned} \tag{43}$$

$$\begin{aligned} & p_k(x,y) = \mathbf{P}(tc_2^{(M)} = x, tc_3^{(M)} = y, m = k) = \\ & \mathbf{P}(tc_1^{(M)} < x,\, tc_2^{(M)} = x, tc_3^{(M)} = y, tc_j^{(M)} \in (y,r] \, (j = \overline{4,k}), tc_{k+1}^{(M)} > r) = \\ & \int_{-\infty}^{\infty} \frac{M!}{(k-3)!(M-k)!} G(x-z)g(x-z)g(y-z) \, [G(r-z) - G(y-z)]^{k-3} \cdot \\ & [1 - G(r-z)]^{M-k} \, dF_{c_2^{(N)}}(z) \text{ for } x \le y \le r \text{ and } k \ge 3 \end{aligned} \tag{44}$$

And the constraint

$$\mathbf{E}\left(c_2^{(N)}\right) = \int_{-\infty}^{\infty} zn(n-1)F(z)\left[1-F(z)\right]^{n-2} dz = 0 \tag{45}$$